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AIR UNIVERSITY UNITED STATES AIR FORCE

SCHOOL OF ENGINEERING

WRIGHT-PATTERSON AIR FORCE BASE, OHIO

THE DESIGN AND SIMPLATION OF A TAKEOFF STABILIZATION

SYSTEM FOR AN AIRCRAFT WITH AN AIR CUSHION LANDING SYSTEM

THESIS

GE/EE/77D-43

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THE DESIGN AND SIMULATION OF A TAKEOFF STABILIZATION SYSTEM FOR AN AIRCRAFT WITH AN AIR CUSHION LANDING SYSTEM

THESIS

Presented to the Faculty of the School of Engineering of the Air Force Institute of Technology

Air University

in Partial Fulfillment of the

Requirements for the Degree of

Master of Science

bу

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Captain

CAF

Graduate Electrical Engineering

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Preface

When the Air Cushion System replaced the conventional takeoff and landing systems of the Jindivik remotely piloted vehicle, the possibility existed that instabilities in pitch, roll, and yaw could occur. As a result, this paper was intended as a design of a Takeoff Stabilization System for the Jindivik using existing autopilot sensors and incorporating an engine yaw thruster and vertical wing tip roll thrusters. When the design was completed, it was sufficiently general that the technique could be applied to any air cushion aircraft or VTOL aircraft. The Landing Stabilization System for the Jindivik using the same sensors and actuators is presently being designed by Captain Max Stafford as his thesis for the Air Force Institute of Technology (AFIT).

I wish to express my gratitude to my Thesis advisors, Dr. George Kurylowich of the Air Force Flight Dynamics Laboratory (AFFDL) and Major R. Potter of AFIT. Also, thanks are due to Captain James Negro of AFIT, Major Jack Randall and Mr. Jim Steiger of the Air Force Flight Dynamics Laboratory for their technical advice and assistance.

My wife, Jane, does not know how much she has contributed to this study, but her patience, understanding, and encouragement has definitely made the past eighteen months of work much easier.

Edward Kenney

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List of Symbols

All symbols are in ft-lb-sec units unless indicated to the contrary.

Alphanumeric Symbols

Symbol

Definition

A

Area

AR =

Aspect Ratio

 α

Horizontal distance between the inner and outer trunk attachment points

Ь

Wing span

C

Wing chord

Сp

Drag coefficient

Coo

Drag coefficient for zero angle of attack and zero elevator angle

Cox

Variation of drag coefficient with angle of attack

CG

Centre of gravity (of aircraft)

CL

$$=\frac{L}{\overline{a}.5}$$

Lift coefficient

Definition

CLO

Lift coefficient for zero angle of attack and zero elevator angle

Variation of lift coefficient with pitch rate

CLE

Coefficient of lift of the tail

$$C_{L_{x}} = \frac{\partial C_{L}}{\partial x}$$

Aircraft lift curve slope

CLKF

Lift curve slope of the vertical stabilizer

CLAK

Lift curve slope of the horizontal stabilizer

CLK2-D

Theoretical two dimensional lift curve slope of an airfoil at 0° absolute

Variation of lift coefficient with rate of change of angle of attack

$$C_{\bullet} = \frac{\chi}{45b}$$

Rolling moment coefficient

 $Ce_{\mathbf{p}} = \underbrace{2U}_{\mathbf{b}} \underbrace{\partial CL}_{\partial \mathbf{p}}$

Variation of rolling moment coefficient with roll rate

Definition

Variation of rolling moment coefficient with yaw rate

$$Cep = \frac{\partial C_L}{\partial B}$$

Variation of rolling moment coefficient with sideslip angle

$$C_m = \frac{27}{\overline{a}} 5c$$

Pitching moment coefficient

$$C_{m} = \frac{21}{4} \frac{\partial C_{m}}{\partial q}$$

$$C_{m} = \frac{21}{6} \frac{\partial C_{m}}{\partial q}$$

Variation of pitching moment coefficient with pitch rate

$$C_{m2} = 2U \frac{\partial C_{m}}{\partial x}$$

Variation of pitching moment coefficient with rate of change of angle of attack

$$C_m = \frac{n}{\bar{q}5b}$$

Yawing moment coefficient

$$C_{mp} = 2U \frac{\partial C_{m}}{\partial p}$$

Variation of yawing moment coefficient with roll rate

$$C_{n\beta} = \frac{\partial C_n}{\partial \beta}$$

Variation of yawing moment coefficient with sideslip angle

$$C_y = \frac{F_y}{\overline{q}'S}$$

Side force coefficient

Side force coefficient for the vertical stabilizer

Symbol []

Definition

$$C_{YP} = \underbrace{\frac{2U}{b}}_{\frac{\partial C_Y}{\partial P}}$$

Variation of side force coefficient with roll rate

$$Cyr = \frac{2u}{b} \frac{\partial Cy}{\partial r}$$

Variation of side force coefficient with yaw rate

$$Cyp = \frac{\partial Cy}{\partial \beta}$$

Variation of side force coefficient with sideslip angle

D

Drag

d

Distance between trunk inner attachment points

F

Force

FAX

Aerodynamic force in the x direction

FAY

Aerodynamic force in the y direction

FAZ

Aerodynamic force in the z direction

FcT

Trunk damping force

FT

Force from the roll thrusters

Symbol	Definition
Fx	Force in the x direction
FXEXT	External force in the x direction
Fy	Porce in the y direction
Fyext	External force in the y direction
Fyt	Force from the yaw thrusters
Fæ .	Force in the z direction
Feet	External force in the z direction
g	Acceleration due to gravity
H₩	Distance between the ground tangent points on the sides of the trunk
Ну	Height of trunk cross section
Ċ	Incidence angle of the hori- zontal stabilizer

AFIT/GE/EE/77D-43 Symbol	<u>Definition</u>
Ixx	Roll moment of inertia of the aircraft about the CG
Ixz	Product of inertia of the aircraft about the CG
Iyy	Pitch moment of inertia of the aircraft about the CG
Izz	Yaw moment of inertia of the aircraft about the CG
k	C _L ² coefficient from drag polar
L . ~	Lift
Ls	Length of the straight part of the trunk
Z	Rolling moment
Z _A	Aerodynamic rolling moment
LEXT	External rolling moment
LTHRUSTERS, LT	Rolling moment of the roll thrusters

Rolling moment of the roll thrusters

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Symbo	1				

Definition

 \mathcal{L}_{F}

Distance from CG to mean aerodynamic chord of vertical stabilizer

LP

Peripheral distance from inner trunk attachment to first row of trunk orifices

lt

Distance from CG to mean aerodynamic chord of horizontal stabilizer

 $lw = \frac{b}{2}$

Length of one wing

M

Number of straight trunk segments in one quarter of trunk periphery

m

Mass

m

Pitching moment

 \mathcal{M}_{A}

Aerodynamic pitching moment

 \mathcal{M}_{ext}

External pitching moment

Ν

Number of curved trunk segments in one quarter of trunk periphery

AFIT/	GE/EE	/?7	7D-4	3
Symbol	l			

Nh

Definition

Number of trunk orifices per row

Nr

Number of rows of trunk orifices

n

Yawing moment

MA

Aerodynamic yawing moment

NEXT

External yawing moment

 η_{yT}

Yawing moment produced by yaw thrusters

P, p

Roll rate (about x axis)
 Pressure

Atmospheric pressure

PAV

PA

Average pressure

PCH

Cushion pressure

PT

Trunk pressure

Q, 9

Pitch rate (about y axis)

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------	------	------	---	---	----	---	---	--

Symbol

<u>Definition</u>

 \overline{q}

Dynamic pressure

Ryr

Yaw rate (about z axis)

5

Reference area (wing)

SF

Vertical stabilizer reference area

5

Horizontal stabilizer reference area

SX

Roll thruster switching curve

SX_{YT}

Yaw thruster switching curve

T

Trunk loop tension force

t

Time

t.

Initial time

+ *

Final time

Uzu

Velocity of CG along x axis

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U(t)

UMAX

UyT MAX

V , ~

Ut

W,w

Xcx

У

Zcx

3F

Definition

Control variable

Maximum roll control

Maximum yaw thruster control

Velocity of CG along y axis (aircraft)

Trunk vertical velocity

Velocity of CG along z axis (aircraft)

Distance of trunk segment centre from CG along vehicle x axis

Distance along wing

Distance of trunk segment centre from CG along vehicle y axis

Mean height of the vertical stabilizer

Greek Symbols Symbol . Definition ~ Angle of attack of aircraft Angle of attack of vertical stabilizer Sideslip angle Angle subtended by curved trunk segment from trunk centre of curvature Downwash angle Elevator angle Şξ Flap angle S(1) Angle of trunk curved segment from centre of curvature Ss Side excursion of trunk \mathcal{E}_{x} Width of straight trunk segment Sweep angle of leading edge

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lizer)

of wing (or horizontal stabi-

Symbol Symbol

Definition

Δ

Mathematical symbol meaning a small change

9

Air density

0

Pitch attitude angle

0P

Inclination angle of lift and drag vectors

Φ

Roll angle

4

()

Yaw angle

Abstract

The inherent instability in pitch and roll associated with an Air Cushion Landing System (ACLS) aircraft at low airspeeds was investigated, and a means to aid control in pitch and roll was developed. The control system required the use of vertical wing tip thrusters which provided thrust up or down depending on the control signal (similar to space vehicle thrusters). These thrusters could be activated alternately to control roll angle and roll rate with the use of a bang-bang optimal controller. As well, the thrusters would be set forward of the aircraft centre of gravity and could be activated in tandum to aid in pitch control.

The Jindivik Remotely Piloted Vehicle, an Australian target drone, was fitted with an ACLS and taxi tests showed the instability and need for a stabilization system. Subsequent use of Jindivik wind tunnel and taxi test data served as the basis for the development of the roll/pitch control system presented in this paper. Due to computational problems with the air cushion model of the computer program, the controller designs could not be completely verified; but expected trends in pitch, roll and yaw control were shown.

THE DESIGN OF A TAKEOFF STABILIZATION SYSTEM FOR AN AIRCRAFT WITH AN AIR CUSHION LANDING SYSTEM Chapter I

Introduction

In the low speed range of a takeoff roll, the normal aircraft controls are not aerodynamically effective; hence, the pilot must control the heading by differential braking and wait until the ailerons become effective to control roll. During this time, the landing gear dampens most of the pitch and roll oscillations so that the pilot has few corrections to make in the latter part of the takeoff roll. However, when the conventional landing gear is replaced by an Air Cushion Takeoff System (ACTS) the pitch and roll damping is greatly reduced. This paper will use the Jindivik Remotely Piloted Vehicle as an example of an air cushion vehicle that can be controlled in the low speed range with the use of small jet thrusters on the wing tips and a thrust deflector on the tail section.

The Jindivik Remotely Piloted Vehicle (RPV) is an Australian target drone that can be launched and recovered on a runway. At present, the takeoff is accomplished with a takeoff dolly, as shown in Fig. 1, that provides a wing level attitude and directional control. At lift off the Jindivik separates from the dolly and the dolly brakes to a stop. Recovery of the Jindivik is done by landing on a single, four inch wide metal skid attached to the fuselage. Directional control during landing is maintained with the ailerons, the rolling moment thus produced

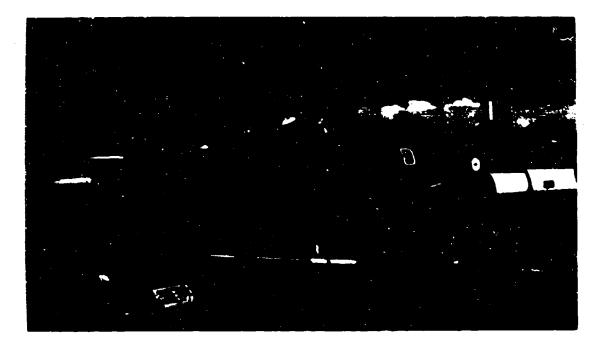


Fig. 1. Jindivik on a Takeoff Dolly makes the drone ride up onto an edge of the skid and turn in the direction of the roll. For the last twelve years the Australian Air Force has used the Jindivik in this configuration with considerable success.

A joint project by the Australian Air Force and the United States Air Force was initiated in 1972 to incorporate an Air Cushion Landing System on the Jindivik. The objectives of this project were to convert the Jindivik to an all-terrain RPV and to advance air cushion technology. The drone and air cushion are shown in Fig. 2. Initial low speed taxi tests, completed in Australia, show that the aircraft fitted with the air cushion is unstable in roll, pitch, and directional control (yaw) (Ref. 13). Therefore, a Stability Augmentation System (SAS) will have

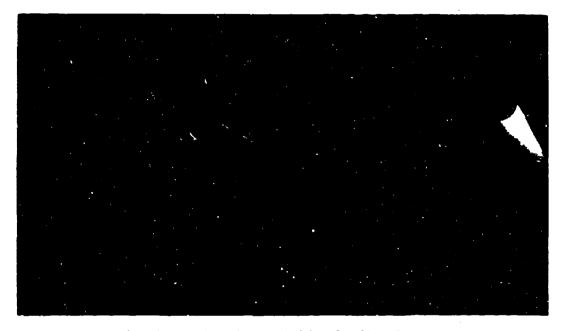


Fig. 2. Jindivik and Air Cushion Landing System to be designed and incorporated into the autopilot before the RPV is airworthy.

Since the drone was designed to be launched from a directionally controlled dolly, it was not designed with a rudder. Implementation of a rudder during this project would require extensive structural changes and major changes to the autopilot and ground control units. Therefore, a yaw thruster was designed and fitted to the rear of the fuselage to direct the jet exhaust, thus providing a yawing moment. Roll and pitch control will be provided by a vertical roll thruster on the front tip of each wing pod. The roll thrusters will be activated alternately to control rolling moments and in tandum to control pitch. Since the roll thrusters are on the tip

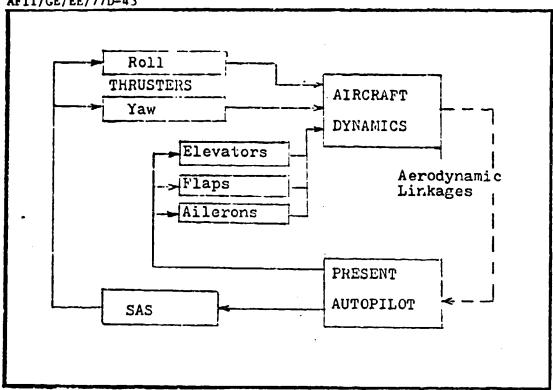


Fig. 3. Block Diagram of Autopilot and SAS Control Units of the wing pods, they are approximately six feet ahead of the centre of gravity of the drone and hence can produce a moment to control the pitch attitude to some degree. As well, the roll thrusters can be directed up or down to counteract positive or negative rolling and pitching moments.

At velocities near fifty knots, the ailerons and flaps become aerodynamically effective and the roll thrusters are phased out to ensure that the vehicle is not overcontrolled. An additional advantage of turning off the roll thrusters is that a smaller gas supply is required for the thrusters. Hence, they can be used with a gas bottle rather than bleed air from the engine. This arrangement will greatly reduce the airframe and engine modifications required for implementation.

The stability augmentation system will be designed to use the existing sensors in the autopilot to control the roll and pitch thrusters. The SAS unit will be placed in the feedback control loop between the autopilot and actuators, as shown in Fig. 3.

This thesis is organized in the following manner: Chapter II develops the equations of motion and aerodynamic stability derivatives, Chapter III describes the air cushion model, Chapter IV discusses the controller design, Chapter V contains a description of the computer program and the simulation results, and Chapter VI the conclusions and recommendations.

Chapter II

The Determination and Solution of the Jindivik Equations of Motion

The following six simultaneous non-linear differential equations fully describe the motion of the Jindivik RPV. The positive sense of the variables is in the direction of the arrows in Fig. 4.

$$m(\dot{u} - VR + WQ) = -mg \sin \theta + F_{AX} + F_{X = XT}$$
 (1)

$$m(\mathring{V} + UR - WP) = mgsiN\phicoso + FAY + FYEXT$$
 (2)

$$m(\dot{W} - UQ + VP) = mg\cos\phi\cos\phi + F_{AZ} + F_{ZEXT}$$
 (3)

$$I_{AA} \dot{P} - I_{XZ} \dot{R} - I_{XZ} PQ + (I_{ZZ} - I_{YY}) RQ = \mathcal{L}_A + \mathcal{L}_{EXT}$$
 (4)

$$I_{yy} \mathring{Q} + (I_{xx} - I_{zz}) PR + I_{xz} (P^2 - R^2) = \mathcal{M}_A + \mathcal{M}_{EXT}$$
 (5)

$$I_{zz}\dot{R} - I_{xz}\dot{P} + (I_{yy} - I_{xx})PQ + I_{xz}QR = \eta_A + \eta_{ext}$$
 (6)

The equations are first order in U, V, W, P, Q, and R with the added kinematic relationships.

$$P = \dot{\phi} - \dot{\Psi} \sin \Theta \tag{7}$$

$$Q = \overset{\circ}{\Theta} \cos \phi + \overset{\circ}{\Psi} \cos \Theta \sin \phi \qquad (8)$$

$$R = \dot{\Psi}\cos\theta\cos\phi - \dot{\theta}\sin\phi \qquad (9)$$

The assumptions used in the derivation of these equations were: (1) the aircraft is a rigid body, (2) the mass of the aircraft is constant for the duration of the analysis, (3) gravity is constant, (4) the earth is an inertial reference, (5) and there is body axis symmetry about the x-z plane (i.e., $I_Xy=O=I_{YZ}$).

Equations (1) to (9) are included in the subroutines of the "EASY Dynamic Analysis Computer Program to Aircraft Modeling"

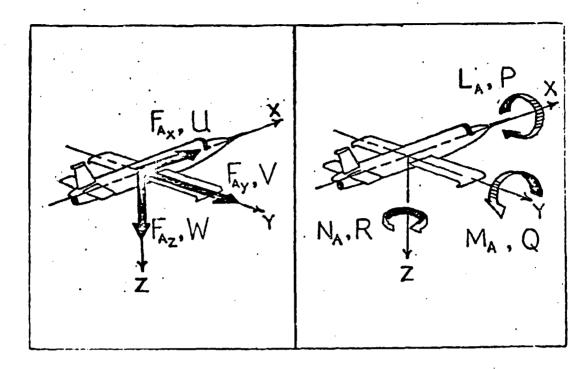


Fig. 4. Definitions of Vector Components in the Equations of Motion

(Ref. 5) which was used to simulate the takeoff motions of the Jindivik. The inputs required by EASY are the mass, inertias, geometry of the aircraft, and the aerodynamic and external forces acting on the drone. The air cushion system is considered to be a prime generator of the external forces and moments (aside from engine forces and moments) and is described in the next chapter. The mass, inertias and geometry are readily available from aircraft blue prints and reference manuals; and the aerodynamic forces and moments can be computed from wind tunnel model data and theoretical methods.

The aerodynamic forces and moments can be written as:

$$L = C_{\ell} \overline{q} S \tag{10}$$

$$D = C_0 \bar{q} S \qquad (11)$$

$$F_{y} = C_{y} \not \in S \tag{12}$$

$$\chi = C_{\ell} \bar{q} 5 \tag{13}$$

$$\eta = C_n \bar{q} S$$
(14)

$$\mathcal{M} = C_{m} \bar{q} 5 \tag{15}$$

where
$$C_{L} = f(u_{3}a_{3}a_{3}g_{3}g_{4}g_{5}g_{5})$$
 (16)

$$C_{D} = f(u_{3}a_{3}a_{5}g_{5}\delta e_{5}\delta f) \qquad (17)$$

$$C_{y} = f(\beta, \beta, \rho, \gamma, S_{A})$$
 (18)

$$C_{\ell} = f(\beta, \beta, P, r, \delta_{A}) \tag{19}$$

$$C_n = f(\beta, \beta, \rho, r, s_A) \tag{20}$$

$$C_m = f(u, \alpha, \lambda, q, \delta_e, \delta_f)$$
 (21)

The coefficients C_L , C_D , C_Y , C_A , C_A , and C_M are non-dimensional. By determining the coefficients for every flight condition, the aerodynamic forces and moments can be calculated and added to the external forces and moments to produce the aircraft motions. These calculations are done by the EASY program but the program requires all the aerodynamic stability derivatives (all the functional relationships which determine the force and moment coefficients). The remainder of this chapter will deal with the derivation of the stability derivatives. These derivatives are derived in the stability axis system as defined by Blakelock (Ref. 2).

Reference 13 contains wind tunnel data for the Jindivik in various configurations, including one when fitted with the Air Cushion Recovery System (ACRS). The ACRS is the air cushion trunk with which the drone lands, but it also has an Air Cushion Takeoff System (ACTS) trunk with which it takes off. After takeoff, the ACTS is disengaged and drops to the ground. Both trunks are the same shape with the ACTS being about 21% larger in all dimensions. Since no wind tunnel data was available for the ACTS, the data for the ACRS was extrapolated by percentages and assumed to be fairly accurate for the ACTS. An example of the estimation technique is that the increase in the frontal area of the aircraft due to the replacement of the ACRS by the ACTS was 6%; therefore, the values of the coefficient of drag ($C_{\rm D}$) were increased by 7%. Since the trunk does not generate lift, the coefficient of lift (C L) was not affected, nor was the coefficient of side force (Cy); symmetry about the x-z axis meant that the coefficient of yawing moment (C_{m}) was not affected. The pitching moment coefficient ($C_{\mathcal{M}}$) and rolling moment coefficient ($C_{\mathcal{A}}$) were affected by the percentage that the increased drag affected those moments. Thus, C_D , C_L , C_Y , C_R , C_m , and C_n can be empirically determined as functions of the angle of attack (\prec), the sideslip (β), and the elevator deflection (S_e). In other words $\frac{\partial C_D}{\partial x}$, $\frac{\partial C_D}{\partial B}$, $\frac{\partial C_D}{\partial S_B}$, $\frac{\partial C_L}{\partial A}$, $\frac{\partial C_L}{\partial S_B}$, $\frac{\partial C_R}{\partial A}$, $\frac{\partial C_R}{\partial A}$, of and can be found from the wind tunnel data.

Non-dimensional derivatives were calculated because they provided a means of checking typical values and signs with

Roskam (Ref. 17) and Blakelock (Ref. 2). Before entering the derivatives into the EASY program, they were dimensionalized.

At low airspeeds the heave motion of the air cushion can create angles of attack beyond the stall limit, but at these speeds aerodynamic contributions to the aircraft dynamics are small.

Stability Derivative Derivation

C_{L}

From a curve of C_L vs. \propto of the wind tunnel data it can be shown that

$$C_{L} = C_{L_0} + \frac{\partial C_{L}}{\partial \alpha} \propto \tag{22}$$

 C_{L_0} and $C_{L_0} \stackrel{\partial}{=} \frac{\partial C_L}{\partial A}$ can be determined directly as the C_L intercept and slope of the curve.

CD

From a drag polar of C_L vs. C_D it can be shown that

$$C_{D} = C_{D_{O}} + KC_{L}^{2}$$
 (23)

where C_{D_0} and K are determined by a curve fit of wind tunnel data of C_D and C_L . Substituting for C_L

$$C_{D} = C_{D_{0}} + K(C_{L_{0}} + C_{L_{N}})^{2}$$

$$= C_{D_{0}} + K(C_{L_{0}}^{2} + 2C_{L_{0}}C_{L_{N}} + C_{L_{N}}^{2} + C_{L_{N}}^{2} + C_{L_{N}}^{2}) \qquad (24)$$

differentiating $\frac{\partial C_0}{\partial \alpha} = K \left(2C_{L_0}C_{L_\alpha} + 2C_{L_\alpha}^2 \alpha \right)$ (25) = $2KC_{L_\alpha} \left(C_{L_0} + C_{L_\alpha}^{\alpha} \alpha \right)$

$$C_{D_{X}} \stackrel{\triangle}{=} \frac{\partial C_{D}}{\partial A} = 2KC_{L_{A}}C_{L} \tag{26}$$

Roskam (Ref. 17, pgs 4.12, 1.18, 4.25) shows that for velocities below 300 ft/sec the variation of lift, pitch moment, and drag with velocity is zero. Thus,

$$\frac{\partial C_0}{\partial u} = 0 = \frac{\partial C_L}{\partial u} = \frac{\partial C_m}{\partial u} \tag{27}$$

The quantities

$$\frac{\partial C_0}{\partial S_c}$$
, $\frac{\partial C_0}{\partial S_c}$, $\frac{\partial C_0}{\partial S_c}$, $\frac{\partial C_m}{\partial S_c}$, $\frac{\partial C_m}{\partial$

CLX

From Roskam (Ref. 17) it can be shown that the angle of attack of the tail in downwash is

$$\alpha_{t} = \alpha - i - \epsilon \tag{28}$$

and for a particular angle of attack

$$\Delta d_{t} = -\Delta \in$$

$$= \frac{\partial \mathcal{E}}{\partial x} \Delta^{x}$$

$$= \frac{\partial \mathcal{E}}{\partial x} \stackrel{?}{\times} \Delta^{t}$$

$$= \frac{\partial \mathcal{E}}{\partial x} \stackrel{?}{\times} \frac{\partial \mathcal{E}}{\partial x}$$
(29)

now the change in lift coefficient on the tail due to downwash is

$$\Delta C_{Lt} = C_{Lxt} \Delta x_t$$

$$= C_{Lxt} \frac{1}{x} \frac{1}{dx} \frac{d\epsilon}{dx}$$
(30)

The change in aircraft lift is

$$\Delta C_L = \Delta C_{Lt} \frac{S_t}{S}$$
 (31)

$$\frac{\partial C_L}{\partial x} = C_{L \neq t} \frac{\ell t}{u} \frac{\partial \epsilon}{\partial x} \frac{St}{S}$$
 (32)

thus
$$(C_{L2})_{TAIL} \stackrel{\Delta}{=} \frac{\partial C_{L2}U}{\partial z} = \frac{2}{C}C_{Lat}l + \frac{5t}{5}\frac{\partial \varepsilon}{\partial x}$$
 (33)

where
$$C_{Ldt} = \frac{AR \cos \lambda C_{Ld_2-D}}{AR \sqrt{1 + \left(\frac{C_{Ld_2-D}\cos \lambda}{TLAR}\right)^2 + C_{Ld_2-D}\cos \lambda}}$$
 (34)

$$C_{L_{\mathsf{X}_{\mathsf{A}-\mathsf{D}}}} = 5.73 \tag{35}$$

 λ is sweep angle and AR is aspect ratio (Ref. 7)

The wing contribution to $C_{L_{\infty}^{2}}$ is considerable but can not be estimated (using Roskam, DATCOM, etc.). So a "typical" value from Roskam of $C_{L_{\infty}^{2}} \simeq 1.5 \, \text{cm}^{-1}$ was used; fortunately this derivative is of minor importance (Ref. 17, p. 4.114).

Cmi

The contribution of the wing was neglected because it will be negligible with respect to the tail contribution. The correction to the pitching moment due to downwash on the tail is

$$(\Delta C_m)_{TAIL} = -\Delta C_{Lt} \frac{St}{S} \frac{Jt}{C}$$

$$= -C_{Lxt} \frac{JE}{S^2} \frac{2}{C} \frac{Jt}{S} \frac{St}{S}$$
(36)

and
$$\frac{\partial C_M}{\partial \dot{x}} = -\frac{C_{LUt}}{C} \frac{\partial \dot{c}}{\partial \dot{x}} \frac{l_t^2}{l_t^2} \frac{5t}{5}$$
 (37)

and
$$C_{m_{\dot{\alpha}}} \stackrel{\triangle}{=} \frac{2U}{C} \frac{\partial C_{m}}{\partial \dot{\alpha}} = -\frac{2C_{L\alpha} + l_{\dot{\alpha}}^{2} S_{\dot{\alpha}}}{C^{2} S} \frac{\partial E}{\partial \alpha}$$
 (38)

CLQ

& changes the angle of attack on the tail by $\frac{dt}{dt}$ radians (for quasistatic conditions)

so
$$\Delta \ll_t = \frac{q lt}{u}$$
 (39)

and
$$\Delta C_L = \frac{S_t}{S} \Delta C_{L_t} = \frac{S_t}{S} C_{L_{N_t}} \frac{Q_t L_t}{Q_t}$$
 (40)

differentiating
$$(\frac{\partial C_L}{\partial q})_{TAIL} = C_{L_{q_1}} \frac{S_{t_2}}{S} \frac{l_{t_2}}{U}$$
 (41)

and the contribution of the wing body is negligible in comparison to the tail (Ref. 17, p. 153)

now
$$C_{L,q} \stackrel{\triangle}{=} \frac{2U}{C} \frac{\partial C_{L}}{\partial q} = \frac{2C_{L,q} + S_{t} lt}{CS}$$
 (42)

Cong

The moment on the tail is

and the change in moment due to a change in angle of attack is

$$\Delta Mt = -\bar{q} lt S_t \Delta C_{Lt}$$

$$= -\bar{q} lt S_t C_{Lx_t} \Delta x_t$$

$$= -\bar{q} lt S_t C_{Lx_t} q$$

$$= -\bar{q} lt S_t C_{Lx_t} q$$
(44)

and

$$\Delta C_{mt} = -q \frac{l_t^2 C_{Lat} S_t}{UCS}$$
 (45)

since the wing contribution is negligible with respect to the tail (Ref. 17, p. 153)

$$C_{mq} \stackrel{\underline{a}}{=} \frac{2U}{C} \left(\frac{\partial C}{\partial S_{TAIL}} - \frac{2l_t^2 C_{Lat} S_t}{C^2 S} \right)$$
 (47)

B Derivatives

Wind tunnel data gave C_y , C_ℓ , and C_m vs. β for values of $/\beta/\le 7^\circ$, but in any takeoff with crosswind the sideslip will normally exceed 7° . The normal takeoff procedure will be to initially line the aircraft into the relative wind at the centerline and change the heading as the aircraft gains speed. This procedure should keep β within $\pm 30^\circ$ and the present data can be curve fitted and extrapolated to this value. Consequently, expressions can be obtained for $C_{y\beta}$, $C_{\ell\beta}$, and $C_{m\beta}$ from the data. The β derivatives have been assumed to be zero (Ref. 17). For the β , ρ , and R derivatives the effect of sidewash on the tail has been neglected.

D Derivatives

CAP

The change in Cn from the tail side force due to roll rate p is

$$(\Delta C_m) tall = -\Delta C_{YE} \frac{S_F l_F}{S_b}$$

$$= -C_{LAE} P J_E S_F l_F$$

$$U S_b$$
(48)

$$\left(\frac{\partial C_{M}}{\partial p}\right)_{\text{tail}} = -\frac{CL_{MF}}{USb} \frac{S_{F}}{S_{F}} \frac{I_{F}}{I_{F}}$$
(49)

where \mathcal{J}_F is the mean height of the fin, and the effect of sidewash has been neglected

80
$$(C_{NP})_{total} = \frac{2U(\partial C_{N})}{b} = -\frac{2C_{L\times F}\partial_{F}S_{F}l_{F}}{Sb^{2}}$$
 (50)

The wing contribution is in two parts due to lift and drag. For positive p the angle of attack is increased on the right wing and decreased on the left; thus inclining and changing the lift and drag vectors of each wing section. The inclination angle is $\Theta_{p} = \underbrace{PY}_{\mathcal{U}}$ where Y is the spanwise coordinate of the section. The change in lift is

$$\Delta Left = \overline{g} C_{L_X} \Delta x C dy$$

$$= \overline{g} C_{L_X} \Delta x C dy \qquad (51)$$

and

where Cdy is the area of the wing section.

So the change in the yawing moment due to lift is

and the total yawing moment of the wing is

$$\Delta \text{Mtdal} = \int_{0}^{\frac{b}{2}} \Delta \text{Mestions} \frac{dy}{dy}$$

$$= -\frac{2\bar{q}cp^{2}C_{Lx}}{U^{2}}C_{Lx}\int_{0}^{\frac{b}{2}}y^{3}dy$$

$$= -\frac{\bar{q}cC_{Lx}p^{2}b^{4}}{32U^{2}}$$
(56)

$$\frac{\partial \mathcal{U}}{\partial P} = -\frac{\overline{q} c p b^4 C_{L\alpha}}{16 u^2} \tag{57}$$

(Cmp) wing lift =
$$\frac{2U}{5\overline{g}b^2} \frac{\partial \mathcal{H}}{\partial P} = \frac{CL_{x} pb^2c}{85U}$$
 (58)

the change in drag is

$$\Delta Def = -\bar{g} C_{D_{\alpha}} \Delta \alpha cdy$$

$$= -\bar{g} C_{D_{\alpha}} D_{\alpha} Cdy \qquad (59)$$

and

the corresponding change in yawing moment is

$$\Delta \mathcal{N}_{eff} = y \, \frac{\bar{q} \, c \, C_{DQ}}{II} \, p \, y \, dy \tag{61}$$

and

$$\Delta \text{Night} = \overline{g} \, \frac{C_{D \times D} \, y^2 \, cdy}{u} \tag{62}$$

80

$$\Delta N_{\text{sections}} = 2 \bar{g} C_{0x} p y^2 c dy \qquad (63)$$

$$\Delta \mathcal{H}_{ttl} = 2 \bar{e} \frac{C C_{D} \alpha P}{u} \int_{0}^{\pi} y^{2} dy$$

$$= \frac{\bar{e} C C_{D} \alpha P}{12 u} \int_{0}^{3} y^{2} dy$$
(64)

$$\frac{\partial \mathcal{H}}{\partial p} = \frac{\bar{g} \cdot C_{DQ} \cdot b^3}{12U} \tag{65}$$

and

$$(C_{mp})$$
duag = $\frac{2U}{5\overline{2}b^2}\frac{\partial \mathcal{H}}{\partial P} = \frac{C_{p\alpha}bc}{65}$ (66)

summing all effects

$$C_{MP} = -\frac{2C_{LR}D_{F}l_{F}S_{F}}{5b^{2}} - \frac{C_{LR}Pb^{2}}{8US} + \frac{C_{DA}b^{2}}{6S}$$

$$= -\frac{2C_{LR}D_{F}l_{F}S_{F}}{5b^{2}} - \frac{C_{LR}Pb}{8U} + \frac{C_{DA}}{6}$$
(67)

Cyp

Cyp is often negligible (Ref. 17, p. 170) and the tail is the major contributor. Let the mean change in angle of attack of the vertical stabilizer (fin) be

$$\Delta K_{F} = -P \frac{3F}{I} \tag{68}$$

where \mathcal{D}_F is the mean height of the fin

now

$$\Delta C_{yE} = C_{L\alpha_E} \Delta \alpha_E$$

$$= -C_{L\alpha_E} \frac{P \Delta E}{d}$$
(69)

so the change on the side force coefficient of the aircraft is (sidewash is neglected)

$$\Delta C_{y} = \frac{S_{E}}{S} \Delta C_{y_{E}} = -\frac{S_{F}}{S} \frac{D}{U} C_{L_{d_{F}}}$$
 (70)

 $\frac{\partial C_{Y}}{\partial P} = -\frac{S_{F}}{S} \frac{C_{L\alpha F}}{U}$ (71)

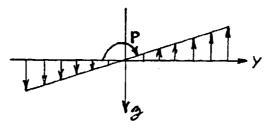
and
$$C_{yp} = \frac{2U}{b} \frac{\partial C_y}{\partial p} = -\frac{2S_F g_F C_{LQ}_F}{S_b}$$
 (72)

Clp

The wing is the only major contributor (Ref. 17, p. 170). Etkin (Ref. 9) shows that the rolling velocity, P, produces a change in the angle of attack of each wing section which is proportional to the span, i.e.,

$$\Delta \alpha = \underline{p} \underline{Y} \tag{73}$$

where y is the spanwise coordinate of the wing section. Then the lift distribution on the wing due to rolling is estimated to be



Etkin (Ref. 9) changes the triangular lift distribution to a sinusoidal distribution to account for the loss of lift at the wing tips due to spanwise flow around the wing tips. However, since the Jindivik has large tip tanks the lateral airflow will be minimized and the lift distribution will be closer to the triangular distribution shown.

The change in lift will be

$$\Delta L = 2 \bar{g} C_{L_X} \Delta x c dy$$

$$= 2 \bar{g} C_{L_X} \underline{c} \underline{p} y dy \qquad (74)$$

and the change in rolling moment due to this lift will be

$$\Delta \mathcal{Z} = -y \, \bar{g} \, C_{L_{\mathcal{A}}} \, \frac{c \, p \, y \, dy}{u} \tag{75}$$

$$J = -\bar{g} \frac{C C_{LQ} p \int_{0}^{\frac{R}{2}} y^{2} dy$$

$$= -\bar{g} \frac{C C_{LQ} p b^{3}}{24 u^{3}}$$
(76)

$$\frac{\partial \mathcal{L}}{\partial P} = -\overline{q} \frac{cCL_{\chi}b^{3}}{24u} \tag{77}$$

and
$$\frac{\partial C_L}{\partial p} \triangleq \frac{1}{8} \frac{\partial \mathcal{X}}{\partial p} = \frac{-C_{L\alpha}b^{\frac{1}{2}}}{524U}$$
 (78)

$$Cl_{p} \stackrel{\underline{a}}{=} \frac{2U}{D} \frac{\partial Cl}{\partial p} = -\frac{Cl_{\alpha}bc}{125} = -\frac{Cl_{\alpha}}{12}$$
 (79)

九 Derivatives

Cyr

The tail is the prime contributor (Ref. 17, p. 174). The change in fin angle of attack due to a yaw rate is

$$\Delta \alpha_F = \frac{r l_F}{\mu} \tag{80}$$

so the change in side force due to the tail is

$$\Delta C_{y} = C_{L_{AF}} \frac{S_{F} r l_{F}}{5 \mu}$$
(81)

$$\frac{\partial C_Y}{\partial r} = C_{L_{AF}} \frac{S_F L_F}{SU}$$
 (82)

$$Cyr \stackrel{?}{=} \frac{2U}{b} \frac{\partial Cy}{\partial r} = \frac{2CL\alpha_F}{5b} \frac{5el_F}{5b}$$
 (83)

Cer

Contributions are from the wing and tail. The side force on the tail acts at $\Delta \varepsilon$, the mean height of the fin

and

$$\Delta F_{y} = \Delta C_{y} \overline{g} S$$

$$= \overline{g} S C_{L_{d_{F}}} \frac{S_{F} R L_{F}}{S U}$$
(84)

now

$$\Delta Z = \Delta F y \mathcal{J} F$$

$$= \bar{g} S \hat{C}_{L \times F} \frac{S F r l_F \mathcal{J}_F}{S \mathcal{U}}$$
(85)

differentiating

$$\frac{\partial \mathcal{L}}{\partial r} = \bar{q} S C_{L \alpha_F} \frac{S_F L_F D_F}{S U}$$
 (86)

and

$$(Cln)_{tul} = \frac{2U}{b} \frac{1}{58b} \frac{dZ}{dz}$$

$$= \frac{2CLUF}{5b^2} \frac{5e^2 F}{5b^2}$$
(87)

A positive A also increases lift on the left wing and decreases it on the right; the change in lift on each wing section is

$$\Delta L_{left} section = \Delta \bar{q} C_L C dy$$

$$= \frac{1}{2} \rho (\alpha y)^2 C_L C dy$$

$$= \frac{1}{2} \rho (\alpha y)^2 C_L C dy$$
(88)

and

$$\Delta L \text{ night section} = -\Delta \overline{g} C_L C dy$$

$$= -\frac{1}{2} \rho (ny)^2 C_L C dy \qquad (89)$$

now the change in rolling moment due to two sections at y is

$$\Delta \mathcal{L} = P \Lambda^2 y^3 C_L cdy \tag{90}$$

and the total rolling moment change for the wing is

$$\Delta X = \rho r^2 C_1 C_2 \int_0^{br} y^3 dy$$

$$= \frac{\rho r^2 C_1 c_2 b^4}{64}$$

$$= \frac{\sigma r^2 C_1 c_2 b^4}{32 u^2}$$
(91)

now

$$\frac{\partial \mathcal{L}}{\partial n} = \frac{\bar{q} \, n \, C_{c} \, c \, b^{4}}{16 \, u^{2}} \tag{92}$$

$$\frac{\partial C_{\ell}}{\partial r_{uing}} = \frac{1}{586} \frac{\partial X}{\partial \Lambda} = \frac{r C_{\ell} b^{2}}{16 u^{2}}$$
(93)

and
$$(Ce_{\lambda})_{uing} \stackrel{\triangle}{=} \frac{2U}{b} \frac{Cl}{\partial r} = \frac{rC_{L}b}{8U}$$
 (94)

summing the components

$$C_{lr} = \frac{2C_{LdF}S_{F}l_{F}B_{F}}{5b^{2}} + \frac{rC_{L}b}{8U}$$
 (95)

CAR

The tail and wing contribute to $C_{M_{\Lambda}}$. Knowing that the change in the fin angle of attack is

$$\Delta \chi_F = -\frac{r l_F}{u} \tag{96}$$

and the moment arm of the tail is $\mathcal{L}_{\mathcal{F}}$ then

so
$$\left(\frac{\partial \mathcal{N}}{\partial n}\right)_{\text{tail}} = -\frac{7}{8} S C_{\text{Log}_F} \frac{S_F l_F^2}{S U}$$
 (98)

$$=-2C_{L_{\alpha_F}}\frac{S_F l_F^2}{S b^2}$$
 (99)

A positive Λ increases the drag on the left wing and decreases drag on the right wing. The change in drag on each wing section is

$$\Delta D = \Delta \bar{g} C_D c dy$$

$$= \frac{1}{2} p C_D (\Delta u)^2 c dy$$

$$= \frac{1}{2} p C_D n^2 y^2 c dy \qquad (100)$$

$$\Delta D = \frac{1}{2} p C_D n^2 y^2 c dy \qquad (101)$$

and

so the change in yawing moment is

$$\Delta \mathcal{H} = -\rho C_0 r^2 c \int_0^{\frac{1}{2}} y^3 dy$$

$$= -\rho C_0 r^2 c b^4 \qquad (102)$$

(101)

now

$$\frac{\partial \mathcal{N}}{\partial n} = \frac{-\rho \, c_D \, n \, c \, b^4}{32} = -\frac{\bar{g} \, C_D \, n \, c \, b^4}{16 \, u^2} \quad (103)$$

and

summing the components

$$C_{MR} = -\frac{2C_{La_F}S_F l_F^2}{Sb^2} - \frac{C_{DR}b}{8U}$$
 (105)

Once all the derivatives had been determined or estimated, Ref. 15 was used to convert to dimentional body-axis derivatives. The derivatives were the written into the EASY program.

Chapter III

The Air Cushion Model

The air cushion model used in this analysis is a truncated version of an ACLS model that was designed by Foster-Miller Associates Inc. of Waltham, Massachusetts for the National Aeronautics and Space Administration (NASA) (Ref. 4).

The basic ACTS configuration is shown in Fig. 5. The model includes four primary subsystems: (1) the fan, (2) the feeding system, (3) the trunk, and (5) the cushion. Air from the fan flows through the ducts and plenum (feeding system) and enters the trunk. The trunk has several rows of orifices that exhaust both to the cushion and the atmosphere. Thus, the airflow from the trunk has two components, one entering the cushion and the other leading directly to the atmosphere. The cushion flow exhausts to the atmosphere through the clearance gap formed between the trunk and ground. In addition to the basic flows described above, two other flows have been included in the model. These are the plenum bleed flow and the direct cushion flow. Plenum bleeding causes some of the air to flow directly from plenum to atmosphere, and has been used in some designs to improve the dynamic characteristics of the air supply system. Direct flow from the plenum to the cushion can also improve dynamic response. A pressure relief valve is also included in the basic configuration. It allows additional flow to vent from the plenum whenever the pressure exceeds a preset level, and thus improves stability by reducing fan stall.

The support force acting on the aircraft is made up of two components.

The first occurs due to the cushion pressure acting over the cushion area.

The second, which comes about only during ground contact, is given by the

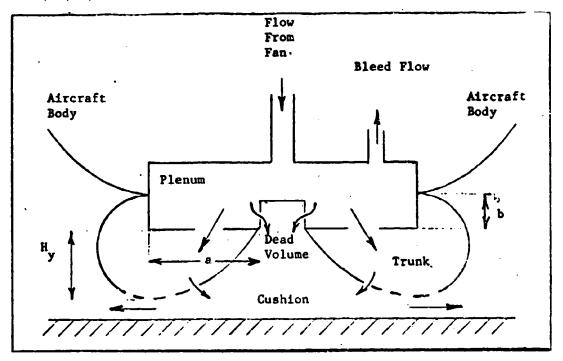


Fig. 5. Basic ACTS Configuration

contact pressure acting over the trunk contact area. The support force, in general, also gives rise to a moment, given by the product of the force and its distance from the CG of the aircraft.

In plan, the cushion has an oval shape, made up of a rectangular section with semicircular ends. The lengths a and b are the horizontal and vertical spacing between the points of attachment of the trunk to the aircraft body. The initial (undeformed) trunk shape is defined by the above two parameters and the perimeter ℓ_P and height ℓ_Y as shown. S_h is the (uniform) spacing between the rows of peripherally distributed orifices. The number of the orifices is selected independently by the number of orifice rows N_r and the number of orifices per row N_h . The cushion volume consists of two parts: an active (dynamically varying) region and a dead (static)

region. The active volume depends on the trunk shape and ground profile. The dead volume, which is a design variable, includes recesses in the cushion cavity as shown.

The forces transferred to the aircraft act through the cushion and trunk. To help calculate these forces, the trunk and cushion are divided into segments as shown in Fig. 6. Each straight section of the cushion and trunk is divided into M rectangular segments, while each curved end is divided into N pie-shaped segments. Thus, the total number of segments is 2 (M + N). All cushion and trunk parameters are calculated first for each segment and then summed to give their total system values.

The dynamic analysis of the vehicle system is best derived with the help of two orthogonal coordinate frames of reference: a coordinate frame fixed in space (inertial frame), and a coordinate frame fixed to the vehicle (vehicle frame) with origin at the aircraft CG.

The reason for two frames can be appreciated by recognizing that:

- (a) Newton's law for translation motion requires that the CG acceleration be expressed relative to the inertial frame.
- (b) The corresponding law for rotational motion, while valid in both inertial and vehicle frames, is applied more conveniently in the vehicle frame, because rotational inertia about any vehicle axis is constant, while the rotational inertia about any inertial (fixed) axis varies with aircraft position.

Accordingly, the two frames of reference have been defined as shown in Fig. 7. The vehicle frame with origin at the aircraft CG

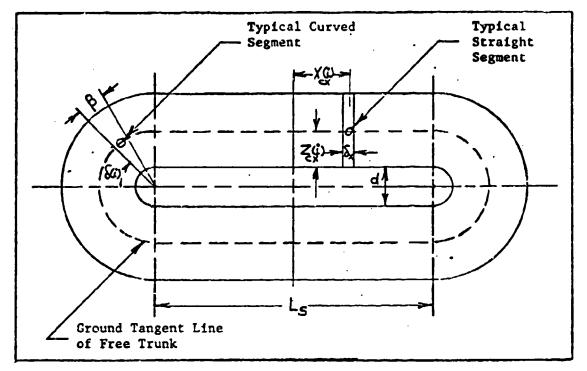


Fig. 6. Division of Trunk Into Segments

has roll, yaw and pitch-axes x, y and z, respectively, fixed to the aircraft body as shown. The inertial frame has corresponding axes X, Y and Z fixed in space. The two frames coincide only when the aircraft has not undergone any rotation from equilibrium.

In the analysis, the actual runway profile underneath the ACTS is approximated by segments that coincide in plan with those of the trunk and are parallel to the cushion hard surface as shown in Fig. 7. With this model, all pressure forces act parallel to the vehicle yaw axis so that the segment torque components about the aircraft CG can be easily computed by multiplying the segment force by the fore-and-aft and/or lateral separation between the segment and the CG.

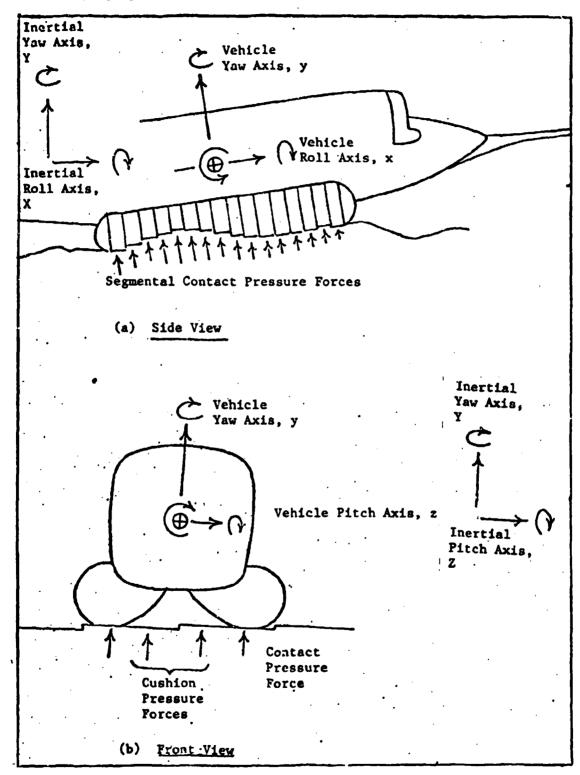


Fig. 7. Inertial and Vehicle Coordinate Frames

The analytical model of the ACTS consists of a set of equations which when solved determines the pressures, flows, forces, and motion of the system for various aircraft and runway parameters. The overall ACTS system is divided into two interrelated systems: the flow system and the force system. These systems are shown in Fig. 8 and Fig. 9.

The flow system establishes the pressure-flow relationship for various subsystems of the ACTS. The force system establishes the corresponding force-motion relationships. The interdependence of the two systems comes about because the trunk deflection obtained from the force system changes the volumes and orifice areas that form part of the flow system. Similarly, the cushion and trunk pressures found from the flow system give rise to forces and moments that form inputs to the force system.

The Trunk Model

The major component of the ACTS model is the trunk model because it determines the trunk shape parameters (volume, and orifice and contact areas), contact pressure distribution and damping that form inputs to the ACLS flow and force systems.

Trunk Shape. In past work, two analytical models have been developed for the trunk shape: the Membrane Trunk Model (Ref. 8) and the Frozen Trunk Model (Ref. 6). The shortcoming of both these analyses was that they modeled the side and end segments of the trunk in the same way while test data now confirm that the shorter curved end segments (front and rear) behave very differently from the longer, straight side segments. Fig. 10 shows the trunk cross section measured at the center of the side and end segments as the load on the cushion is increased. The entire side segment tends to bow outward and avoid ground contact, while the end segment remains virtually fixed, except for a flattening

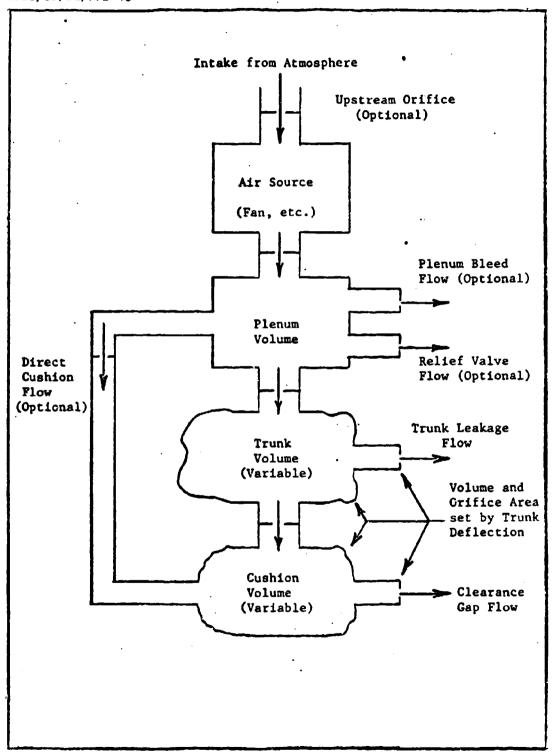


Fig. 8. ACTS Flow System

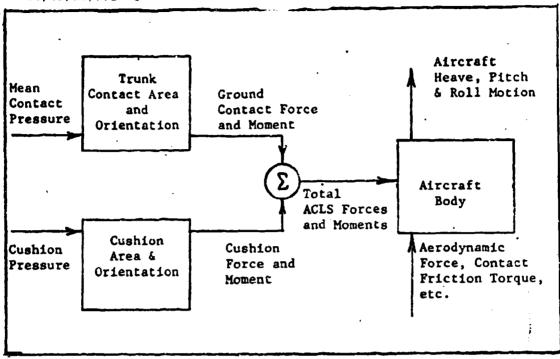


Fig. 9. ACTS Force System

in the region that actually touches the ground. This difference in behavior occurs because the front segment is much smaller than the side segment and is curved. When the cushion pressure increases due to an increase in the load, the radially outward force causes the oval trunk planform to become more circular, as shown in Fig. 11. This causes a hoop tension force, T, to act around the trunk periphery. In the side segments, this force acts substantially normal to the side excursion, S_s , so that its component resisting the motion is negligible and the side segment can thus bow outwards relatively unrestrained. In the end segments the situation is different, since the curvature of the segment causes the hoop tension to have a much higher component opposing the motion so that outward motion of the trunk ends is much smaller.

C

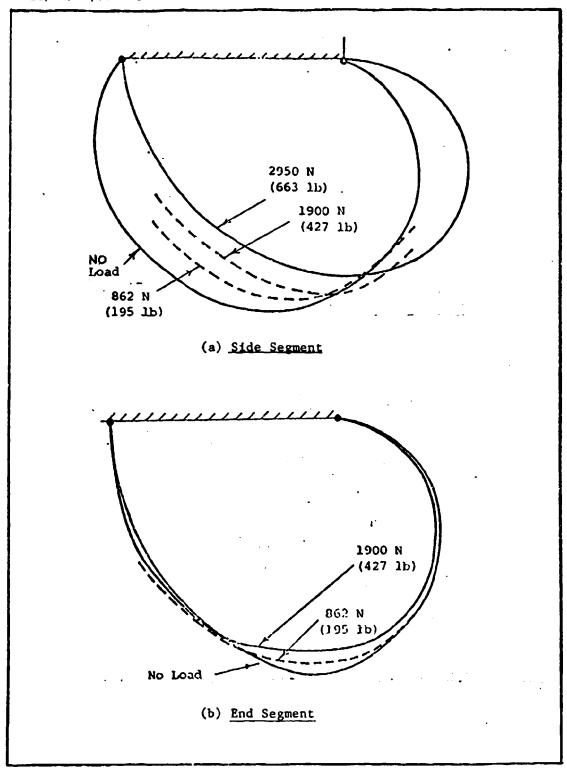


Fig. 10. Measured Trunk Profile

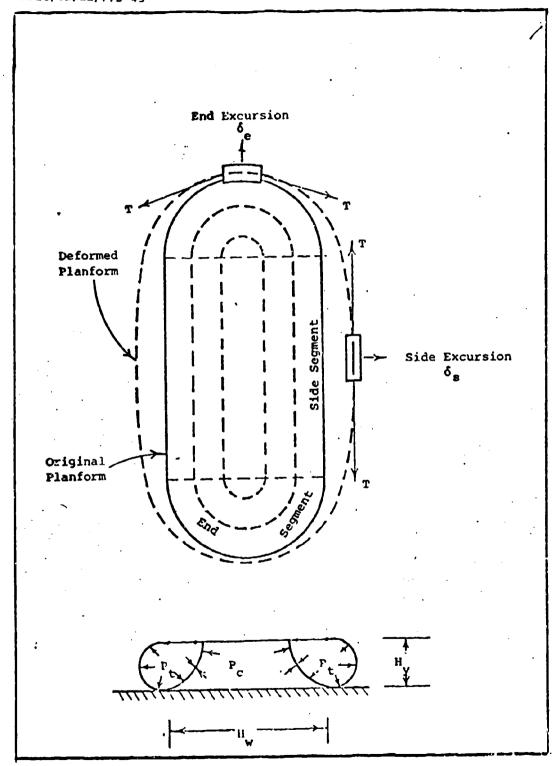


Fig. 11. Outward Excursion of Trunk Segments

Since hoop tension has very little effect on side trunk motion, the side segments can be considered as simple, two-dimensional membranes, as done in the Membrane Trunk Model. On the other hand, the fact that hoop tension restrains ("freezes") the trunk ends suggests that these segments be modeled by the Frozen Trunk Model. Thus, the logical step in trunk model improvement is to combine the two existing models and form the Hybrid Trunk Model, in which the sides are represented by the Membrane Model and the ends by the Frozen Model.

The Hybrid Trunk Model is essentially a limiting case analysis of trunk deflection. In general, best results will be obtained at the middle of the respective segments, i.e., at the center of the side segments, where the trunk behaves very much like an ideal membrane, and at the center of the end segments, where the trunk shape is truly fixed. In the transition region (at and near where the segments meet), the trunk will exhibit properties of both the membrane and frozen trunk approximations.

Contact Pressure. In addition to trunk and cushion shape, the trunk model also determines the pressure distribution in the ground contact zone. The analysis for pressure distribution is complicated by the fact that two separate effects must be considered: direct trunk-ground contact caused by the trunk pressure forcing the trunk against the ground, and airflow through the trunk holes into the interstices that remain in the contact zone.

4

When two bodies in contact are acted upon by a force, F, the actual contact occurs at a number of discrete regions rather than over the whole area, due to the inherent roughness of the contacting surfaces as shown in Fig. 12. Because the number of contact

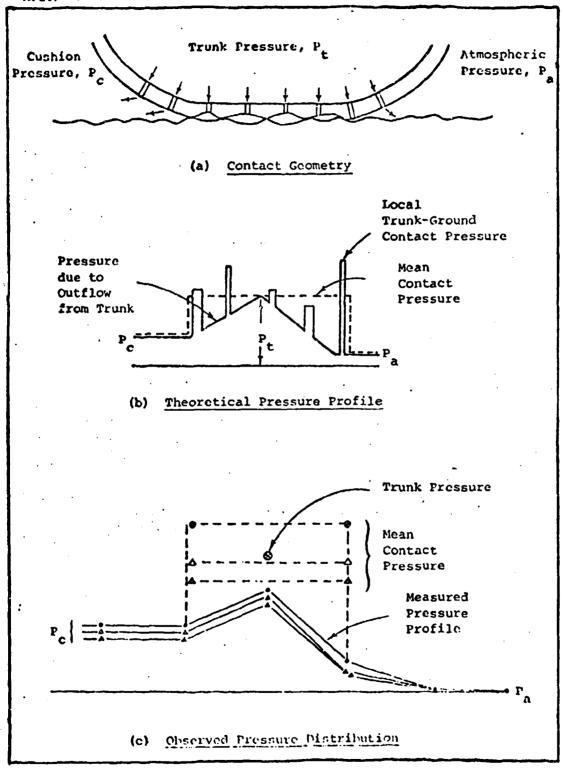


Fig. 12. Pressure Distribution in Trunk Contact Zone

regions is large for a "smooth" surface, it was convenient to define an average contact pressure, Pav = F/A, acting as though the bodies were touching uniformly over the entire area, A. In fact, $P_{\rm av}$ equals the trunk pressure, Pr. For purposes of trunk outflow calculation, the pressure profile in the non-contacting regions is approximated by a linearly decreasing relationship as shown in Fig. 12. The driving pressure for flow through any trunk hole is thus given by the difference between the trunk pressure and the gap inclose that location. This pressure distribution model has been compared to experimental data and has been quite accurate (within 10%) (Ref. 4). Trunk Damping. In dynamic operation, the trunk is deformed cyclically both in tension and flexure, and energy dissipation in the trunk material gives rise to a damping force which opposes the strain tate. Because the present trunk analysis does not solve for strain (and hence strain rate), a damping model that links trunk material properties directly to trunk damping forces cannot be developed. An alternate approach in which the damping characteristics are modeled by dimensional analysis (similarity) based on test data thus appears more appropriate. In keeping with the method of approach outlined earlier, the trunk is divided into segments (Fig. 13) and a series of dashpots, one for each

Each dashpot models the energy dissipation characteristic of the trunk segment. Although all parts of the trunk dissipate energy, the major contributions will come from those parts that undergo high stress reversals, since the strain rate is highest in these sections. Observations of a trunk in dynamic operation suggest that the high

segment, is included in the model such that the segment damping force

is proportional to the vertical velocity of the trunk segment.

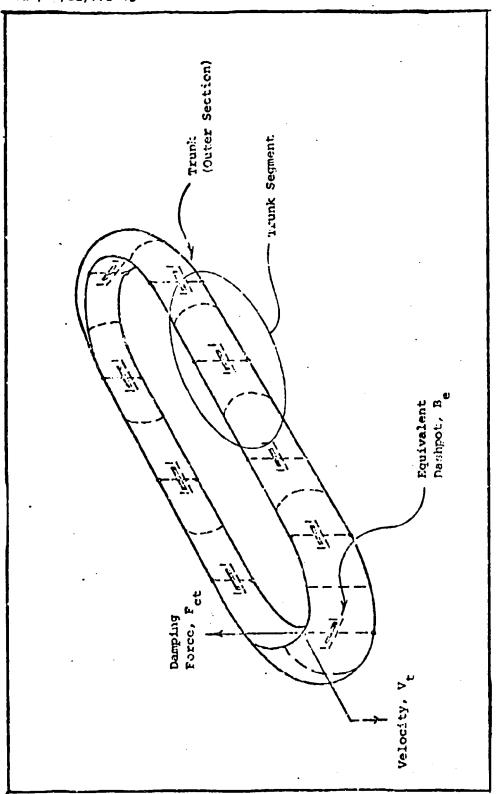


FIG. 13. The Trunk Damping Model

stress reversal regions lie along the periphery of the trunk-ground contact zone, because it is here that the rate of change of trunk slope (and hence stress) is high and constantly changing with the time as the contact area changes. As a first order approximation, the damping model derived here assumes that all the energy dissipation in the trunk is concentrated along the trunk-ground contact periphery so that the damping coefficient of each dashpot depends on the perimeter of the ground contact zone. This means that when a segment is not contacting the ground it has zero damping and when it is contacting the ground it has a damping coefficient proportional to the contact perimeter.

Model Synopsis

The Flow System

- (a) The fan is characterized by a static pressure rise element for forward and back flow in series with an inertance (duct) and a capacitance (volume).
- (b) The trunk and cushion volume are found from the Hybrid Trunk Model, which characterizes the side trunk segment as an ideal two-dimensional membrane and the end segment as a "frozen" trunk.
- (c) The orifice areas between the trunk and cushion, trunk and atmosphere and cushion and atmosphere are found from the trunk shape as predicted by the Hybrid Trunk Model, along with the cushion orientation and ground profile.
- (d) The pressure within the cushion, trunk and plenum is considered to be uniform.
- (e) The pressure in the trunk/ground contact zone is found from the triangular profile given by the Hybrid Trunk Model.

- (f) The flow through the plenum, trunk and cushion is governed by the unsteady state flow continuity equation in which the air is assumed to behave like a perfect gas and follow a polytropic expansion relationship.
- (g) The flow through all orifices is found from the incompressible flow square-law orifice equation.

The Force System

- (a) The mean contact pressure in the trunk/ground contact zone is equal to the trunk pressure.
- (b) The trunk contact area and location relative to the aircraft CG is found from the trunk shape predicted by the Hybrid Trunk Model.
- (c) The cushion area and location relative to the aircraft CG is found from the Hybrid Trunk Model. In width, the cushion extends between the lowest (ground tangent) points of the side trunk segments. In length, it extends between the ground tangent points of the end trunk segments, or, if in ground contact, between the inner edges of the contact zone.
- (d) The total forces and moments acting on the aircraft occur due to the mean trunk contact pressure acting over the contact area, the cushion pressure acting over the cushion area, serodynamic drag and trunk damping losses caused by aircraft heave motion, and trunk-ground friction.
- (e) The forces and moments are found by dividing the cushion (and trunk) into segments, approximating the actual ground profile underneath the cushion by a similar set of segments parallel to the cushion, computing the cushion and contact pressure forces and moments for each segment, and then summing them to determine the total force

and moment about the sircraft CG.

- (f) The heave motion of the aircraft is found by applying Newton's law in the vertical direction to the aircraft CG.
- (g) Angular accelerations in pitch and roll are obtained by applying the theorem of moment of momentum about the aircraft pitch and roll axes.
- (h) A coordinate transformation is carried out to express vehicle frame velocities and accelerations in terms of Euler angles and their derivatives.
- (i) The moment of momentum equations, expressed in terms of Euler angles are integrated to give the angular position of the aircraft as a function of time.

Chapter IV

Controller Design

During the low speed portion of the takeoff roll (to approximately 50 knots), the controls available are a yaw thruster on the rear fuselage and vertical roll thrusters on each wing tip. The roll thrusters can be directed up or down. During the takeoff sequence, the most unstable mode of the aircraft is the roll mode. Therefore, it was decided to control this mode and observe the control that was applied to the pitch mode through the inertial cross-coupling. Also, during takeoff the yaw angle will be controlled by the yaw thruster on the rear of the fuselage. With roll and yaw controlled, Eqn (4), which is rewritten here, can be simplified.

$$I_{MN} \dot{P} - I_{N3}(\dot{R} + PQ) + (I_{22} - I_{yy})RQ = \chi$$
(106)

Controlling roll and yaw means that R will be small and PQ and RQ (products of small numbers) will be small. Q can be considered small because the takeoff starts with zero initial conditions on P, Q, and R. With the above simplification and assuming that any roll inputs from the ground profile are impulsive, then the roll moment generated by the roll thrusters can be written as

IXX
$$\dot{\phi} = \mathcal{L}_{THRUSTERS}$$

$$= \mathcal{L}_{W}F_{T} \tag{107}$$

$$\mathfrak{F}(t) = \mathbb{C} \, \mathsf{F}_\mathsf{T}(t) \tag{108}$$

where
$$C = \frac{l_{xx}}{L_{xx}} = 8.28 \times 10^{-3}$$

now let
$$N_1 = \phi$$
 (109)

$$\mathcal{N}_{2} = \emptyset \tag{110}$$

and $u(t) = F_{T}(t) \tag{111}$

so Eqn (108) can be rewritten as

$$\dot{x}_2(t) = C U(t) \tag{112}$$

and

$$\dot{x}_{1}(t) = x_{2}(t)$$
 from Eqn (110) (113)

so
$$\underline{\dot{x}}(t) = \begin{bmatrix} 0 & 1 \\ 0 & 0 \end{bmatrix} \underline{x}(t) + \begin{bmatrix} 0 \\ c \end{bmatrix} \underline{u}(t)$$

$$\underline{A} \qquad \underline{B} \qquad (114)$$

For a minimum time Performance Index and for $|U(t)| \leq U_{max}$ an optimal control for this system can be shown to be a bang-bang control (Ref. 14, pgs 245-248). In other words, the control is a maximum (either positive or negative) whenever it is applied. Since the eigenvalues for \underline{A} are both zero, Theorems 5.4-1 and 5.4-3 of Kirk (Ref. 14) show that an optimal control exists, is unique and has at most one switching.

Therefore, the control for a specified initial state must be

$$U^*(t) = -\frac{1}{2} U + \frac{1}{2} U + \frac{1}{2$$

(115)

Integrating Eqns (112) and (113) with $U=\pm U_{max}$ gives

$$(116)$$
 = $C \int U(4) dt$
= $\pm C.U_{max} t + CC_2$

where C_z is the value of x_z at $t = t_o$

and

$$x_{i}(t) = \int x_{i}(t) dt$$

= $\int (\pm C ll_{max} t + CC_{i}) dt$

where C, is the value of x, at t= to

solving for t in (116)

$$t = \underbrace{x_2(t) - CC_2}_{t \in U_{max}}$$
 (118)

substituting t into (117)

$$\chi_{1}(t) = \frac{t}{2} \frac{C U_{max}}{(y_{2}^{2}t)} - 2CC_{2}\chi_{2}(t) + C^{2}C_{2}^{2}$$

$$+ \frac{CC_{2}(\chi_{1}t) - CC_{2}}{t} + C_{1}$$
for $U = + U_{max}$

$$(119)$$

$$x_{i}(t) = \frac{1}{2CU_{max}} x_{i}^{2}(t) - \frac{C_{2}x_{i}(t)}{U_{max}} + \frac{CC_{i}^{2}}{2U_{max}} + \frac{C_{2}x_{i}(t)}{U_{max}} - \frac{CC_{i}^{2}}{U_{max}} + C_{i}$$

$$= \frac{1}{2CU_{max}} x_{i}^{2}(t) + C_{3} \qquad (120)$$

where

$$C_3 = C_1 - \frac{CC_2}{2U_{max}}$$
 (121)

for
$$U = -U_{max}$$

$$\chi_{1}(t) = \frac{-1}{2CU_{max}} \frac{\chi_{2}^{2}(t) + C_{2}\chi_{2}(t) - C_{2}^{2} - C_{2}\chi_{2}(t) + C_{2}^{2} + C_{1}}{U_{max}} \frac{\chi_{2}^{2}(t) + C_{2}^{2} + C_{1}}{U_{max}} = \frac{-1}{2CU_{max}} \frac{\chi_{2}^{2}(t) + C_{4}}{U_{max}}$$
(122)

where
$$C_4 = C_1 + \frac{CC_2^2}{2 U_{max}}$$
 (123)

the switching curve is

$$N_{1}(t) = \frac{1}{2C y_{\text{max}}} N_{2}(t) \left| N_{2}(t) \right|$$
(124)

Let
$$SX = \chi(t) + \frac{1}{2C \text{ Umax}} \chi_2(t) |\chi_2(t)|$$
 (125)

80
$$U^*(t) = -\frac{1}{2} - \frac{1}{2} \frac{1}{$$

It can be noted that this controller design is almost completely independent of the aircraft type. In the low speed range where aerodynamic controls are not effective, this design will help stabilize the roll mode of any aircraft. The only relationship between the aircraft and controller is that the thruster force is a function of roll inertia and wing span. Thus, this design becomes very versatile

and applicable to stabilize the roll mode of any ACLS aircraft.

A somewhat similar analysis will be made for the controller of the yaw thruster. The criterion for directional control is to keep the aircraft on the runway centreline during takeoff; this can be accomplished by minimizing the lateral deviation, y, and rate of deviation from the centreline, y. This deviation and rate will be minimized by yawing the aircraft in a direction to oppose the disturbance with the use of the yaw thruster.

Prior to the installation of the air cushion, the directional stability of the Jindivik was controlled by a batsman at the end of the runway. His job was to steer the dolly (Fig. 1) to keep the aircraft on the centreline. The same batsman will visually sense lateral deviation and deviation rate and control the yaw acceleration to indirectly control the lateral deviation and rate.

Assuming that the pitch and roll angles are kept small, then the lateral acceleration (to correct a lateral displacement) in the inertial frame of reference of the runway is a function of the thrust and yaw angle.

and since \forall will be small (<30°) to keep the aircraft on the runway centreline, then

Equation 128 can be implemented as shown in Fig. 14. With these control loops the desired yaw angle to zero lateral displacement

can be determined. Referring to Fig. 14

$$\Psi_{d} = -K_1 \dot{y} - K_2 \dot{y} \tag{129}$$

the inner loop open loop transfer function is

$$(GH)_{I} = \frac{KK_{I}}{S} \tag{130}$$

and the equivalent closed loop transfer function is

$$G_{1} = \frac{GH}{1+GH}$$

$$= \frac{KK_{1}}{5+KK_{1}}$$
(131)

the outer loop open loop transfer function is therefore

$$(GH)_{Z} = \frac{G_{1}K_{2}}{S}$$

$$= \frac{KK_{1}K_{2}}{S(S+KK_{1})}$$
(132)

this gives a root locus as shown in Fig. 15. For a damping ratio of 0.7 the closed loop roots are located at $\left(-\frac{KK_1}{2}, -\frac{KK_1}{2}\right)$, which gives a closed loop transfer function of

$$G_{2} = \frac{K K_{1} K_{2}}{\left(S + \frac{K K_{1}}{2} \pm j \frac{K K_{1}}{2}\right)}$$

$$= \frac{K K_{1} K_{2}}{S^{2} + K K_{1} S + \frac{K^{2} K_{1}^{2}}{2}}$$
(133)

but

$$G_2 = \frac{(GH)_2}{1 + (GH)_2}$$

$$= \frac{K K_1 K_2}{5^2 + K K_1 S + K K_1 K_2}$$
 (134)

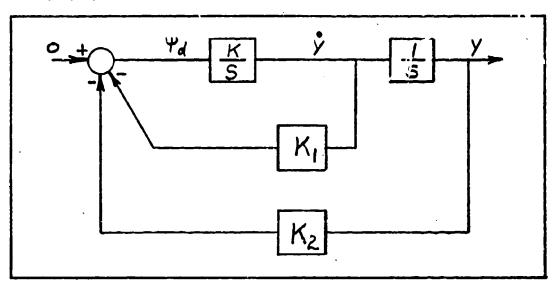


Fig. 14. Feedback Control Loops for Lateral Acceleration

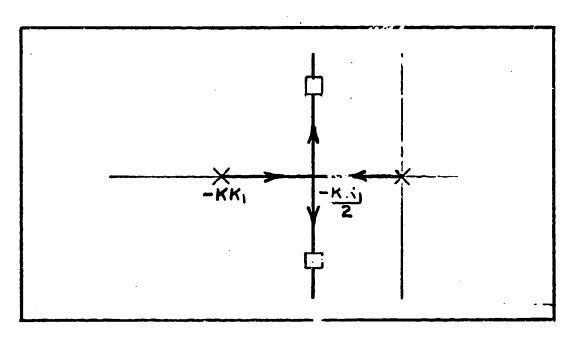


Fig. 15 Root Locus for Fig. 14

therefore equating denominator coefficients gives

$$KK_{1}K_{2} = \frac{K^{2}K_{1}^{2}}{2}$$

$$K_{2} = \frac{KK_{1}}{2}$$

$$= 9.1 K_{1}$$
(135)

or

Since K_1 is arbitrary, a value of 0.3 was selected, so

$$K_1 = 0.3 \tag{136}$$

and

$$K_2 = 2.73 \tag{137}$$

so the desired yaw angle is

$$4d = -0.3\dot{y} - 2.73y$$
 (138)

The yaw angle is associated with the yaw thruster force by

$$I_{33}\ddot{\Psi} = \mathcal{N} = F_{YT} l_{w}$$

$$\ddot{\Psi} = C_{5} F_{YT}$$
(139)

where

$$C_5 = 2.73 \times 10^{-3} \tag{140}$$

in matrix form

$$\begin{bmatrix} \dot{\psi} \\ \dot{\psi} \end{bmatrix} = \begin{bmatrix} 0 & 1 \\ 0 & 0 \end{bmatrix} \begin{bmatrix} \psi \\ \dot{\psi} \end{bmatrix} + \begin{bmatrix} 0 \\ C \end{bmatrix} F_{yT}$$
(141)

This equation is the same as Eqn. 114 for the roll thruster, and similarly a bang-bang control exists for which the switching function

is

$$SXYT = \Psi + \frac{\dot{\Psi} |\dot{\Psi}|}{2C F_{YTMAX}}$$
 (142)

and the optimal control law is

$$F_{YT} = -F_{YTMAX}, SXYT > 0$$

$$F_{YTMAX}, SXYT < 0, \Psi > 0$$

$$F_{YTMAX}, SXYT = 0, \Psi < 0$$

$$F_{YTMAX}, SXYT = 0, \Psi < 0$$

$$0, \Psi = 0, \Psi = 0$$
(143)

The implementation of this control law would drive the yaw angle and yaw rate to zero in the minimum time, but the directional control problem requires that the yaw angle be equal to the desired angle, Vd. This can be accomplished by shifting the switching curve by the amount Vd.

$$SXYT = \Psi - \Psi d + \frac{\psi |\psi|}{2CFyrnax}$$
 (144)

This change in the switching curve means that the yaw rate and the quantity ($\Psi - \Psi d$) will be driven to zero in the minimum time, or Ψ will equal Ψd .

Chapter V

The Computer Program and Simulation Results

General

formed the major portion of the computer analysis and simulation and the air cushion system was modelled by the Foster-Miller model, as described in Chapter III. The computer program is listed in Appendix B. In brief, the EASY program provided the means for an analysis of the six degree of freedom rigid body dynamics of the Jindivik drone and the Foster-Miller model estimated the ground forces and moments transferred by the air cushion to the airframe. Additional FORTRAN was used to reflect the Jindivik autopilot and the designed roll, pitch and yaw controllers in the EASY program. Simulations were performed to obtain time history comparisons of the uncontrolled and controlled aircraft models with a crosswind driving function and an initial pitch angle to simulate flying off of a 2 inch step.

The Computer Program

Figures 16, 17, and 18 show the computer block diagrams of the aircraft dynamics, the longitudinal autopilot, and the lateral autopilot, respectively. Understanding the symbology used in these figures would require considerable referral to Reference 5, but a general description of the schematics will be given here.

In Figure 16, SD performs the six degree of freedom rigid body dynamics, AV calculates the aerodynamic variables, LO calculates the longitudinal force and moment sum, and LD calculates the lateral force and moment sum. The terms FX3S2, FZ3S2, TY3S2, TY3S2, TX3S2, and TZ3S2, shown feeding into LO and LD, are the sums of the engine and external

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Fig. 16. Block Diagram of Aircraft Dynamics

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Pig. 17. Block Diagram of Longitudinal Autopillot

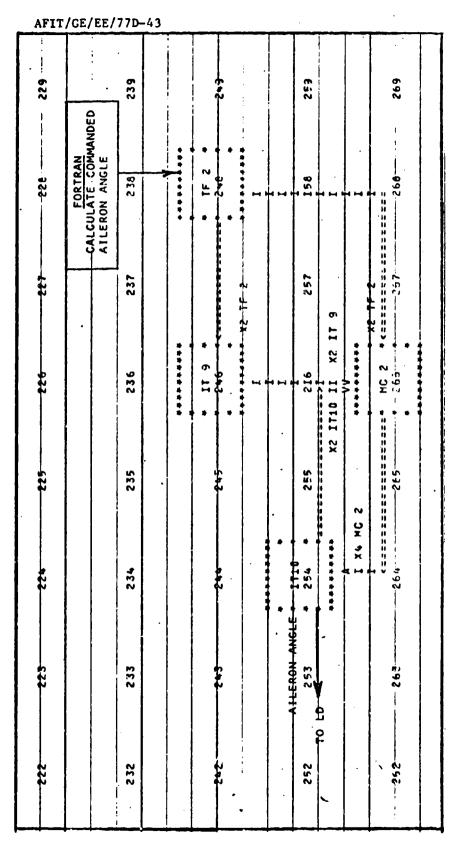


Fig. 18, Block Diagram of Lateral Autopilot

(i.e. air cushion system and controller) forces and moments.

The longitudinal and lateral autopilot functions shown in Figures 17 and 18 were developed from the elevator and aileron transfer functions given in Reference 3. The maximum deflection of the control surfaces, the gearing ratios between control surfaces and servos, and the maximum slewing rates for the servos were also programmed into the model by FORTRAN.

Air Cushion Program

The air cushion system was programmed with ten subroutines to the EASY program and the flow chart of the subroutines is shown in Figure 19. The functions of the ten subroutines are as follows: FM is the main subroutine which calls and interacts with the remaining subroutines; it also determines the appropriate fan curve and contains the integration routine. HC, TK, SE, CO, PR, CL, S1, and SP form a set of subroutines which need the aircraft position, cushion and trunk pressures and ground profile as input parameters and they calculate various areas and volumes associated with those parameters. HC calculates the value of side trunk height for a given cushion to trunk pressure ratio. Subroutine TK takes that height and calculates trunk cross section parameters. From these parameters SE updates the trunk division parameters. Subroutine CO transforms position vectors for each trunk centre, from the vehicle frame to the ground frame, and then calculates the distance between each of the trunk segments and the ground, and it also calculates the ground coordinates above which each of the segments lie. Subroutine PR determines ground elevations (input by user) corresponding to the

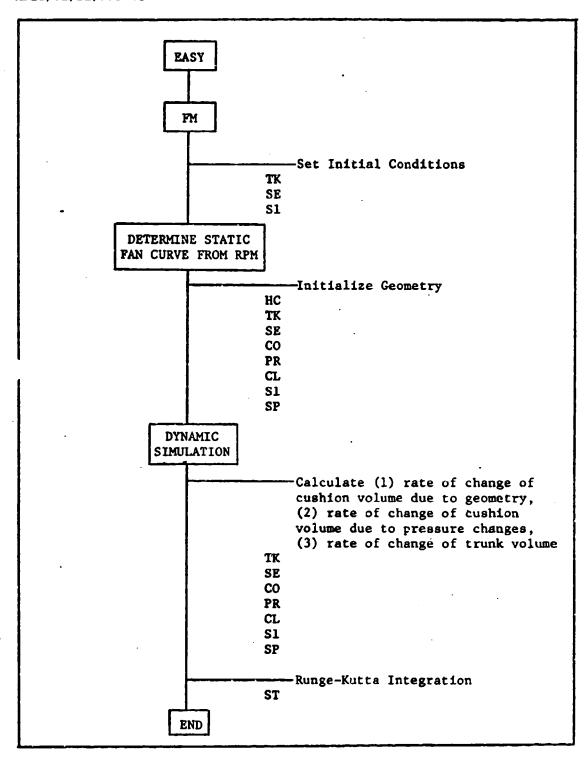


Fig. 19. Air Cushion Subroutine Flow Chart

ground coordinates generated by CO, and subroutine CL determines the hard surface clearance for each segment using (a) the ground elevation value and (b) the distance of the trunk segment from the ground. Finally, subroutine SP calculates values of different areas and volumes for each segment and adds them together to give total areas and volumes.

In addition to these seven subroutines, FM also calls subroutine ST. ST determines the value of fan flow for a given
value of fan pressure rise and also calculates the forces and
torques for a given ACTS orientation. Subroutine ST also incorporates all the system differential equations so that the
value of the state differentials can be updated each time it
is called by the Runge-Kutta integration routine. The forces
and torques calculated by ST are passed to the EASY program
via FM.

Simulation Results

The results of the simulation to test the controller designs of Chapter IV are shown in Tables I and II. For initial conditions of -1° in pitch, 0° in roll, and a constant 40 ft/sec crosswind, the uncontrolled model induces a roll angle and pitch angle that are lightly damped in comparison to the controlled model. Also, the restoring yaw angle is less than the controlled yaw angle and the lateral deviation, y, is subsequently greater for the uncontrolled model. The 1.5 second simulation for the uncontrolled model required 15,000 seconds of computation time and consequently the simulation was not continued to the extent

Table I - Simulation Results Uncontrolled Model

TIME	PITCH	ROLL	WAY	ALTITUDE	LATERAL DEVIATION
0.0	-1.000	0.000	0.00	2.60	0.00
0.5	. 305	.113	63	1.52	3.84
1.0	.451	.474	-1.94	1.02	8.78
1.5	.377	.142	-2.51	1.25	14.87

Table II - Simulation Results Controlled Model

TIME	PITCH	ROLL	YAW	ALTITUDE	LATERAL DEVIATION
0.0	-1.000	0.000	0.0	2.60	0.00
0.5	.273	.150	74	1.71	3.83
1.0	.282	.072	-2.05	1.25	8.77
1.5	.063	.023	-3.82	2.32	14.68
2.0	.038	.005	-5.99	2.31	21.23
2.5	.045		-8.52	2.27	27.87
3.0	.052		~11.37	2.23	34.12
3.5	.048	İ	-14.46	2.32	39.56
4.0			-17.70	2.32	43.74
4.5			-21.10	2.32	46.22
5.0		1	-24.50		46.52
5.5		j	-27.80		44.15
6.0	į	1	-30.90		38.56
6.5	Ţ	. ↓	-33.40	₩	29.21
7.0	Y	J	-34.80	. ▼	15.69

Chapter VI

Conclusions and Recommendations

The National Aeronautics and Space Administration (NASA) has accepted the Foster-Miller program as a valid air cushion model; however, in the course of the analysis of this thesis, several problems arose which prevent this program from becoming an effective design tool. The primary problem is the excessive computation time required for dynamic simulation when it is incorporated with the EASY Dynamic Analysis Program. The Fourth Order Runge-Kutta integration routine used in the air cushion model requires a time increment of 0.001 seconds for numerical stability. Since this integration routine is the prime reason for the excessive computation time, it is recommended that the routine be changed or augmented to reduce computation time.

The air cushion model assumes that the trunk is an elliptical shape rather than the actual shape, in which the aft end is 10% wider than the fore end. This discrepancy impinges on trunk and cushion volumes and areas, pitching and rolling moments, clearance and gap areas, etc. In other words, it requires considerable evaluation and extensive modification and verification of the program to change trunk shapes. It is recommended that Foster-Miller Associates be asked to modify their model to accommodate different trunk shapes as future designs may require.

The air cushion model has no provision to orient the trunk orifices other than perpendicular to the trunk surface. In fact, the Jindivik trunk orifices are drilled inward at a 45° angle to produce more cushion pressure in the region of trunk contact. Some adjustment should be made to the model to allow this orifice orientation as a design parameter. Also, the model uses a single curve to describe the fan characteristics of outflow vs. drive pressure, but the actual characteristics dependent on more variables; hence, a fan "map" is required to replace the single curve and adequately describe the fan during all phases of its operation.

A weak part of the computer simulation is the evaluation of the Jindivik Stability Derivatives due to the fact that the static wind tunnel data was extrapolated from the Recovery Trunk Data and was suspect from the beginning of the analysis. Consequently, it is recommended that wind tunnel tests be conducted in a moving belt tunne— Ith the takeoff trunk and with measurement of the rate variables p, q, and r. Barring this option, the development of the derivatives should be reviewed and ammended with the use of more sophisticated data reduction techniques. Once the computer program, shown in Appendix B, is changed to encompass the previous recommendations, it can be used to define the following parameters:

- a) Operational limits and directions of crosswinds.
- b) A "ground roughness" criteria above which the aircraft becomes unstable.

- c) A flap deflection schedule to provide minimum takeoff distance within pitch stability. The present two flap settings would provide a step input to pitch and hence should be changed.
- d) All of the above for different vertical thruster sizes and locations.

This thesis has integrated the EASY Dynamic Analysis Program and a truncated version of the Foster-Miller air cushion model to simulate an air cushion vehicle during takeoff. During the process of that integration and simulation, some major deficiencies in the Foster-Miller model have been highlighted. This thesis has also developed and demonstrated a technique to control bangbang thrusters on the wing tips and a bang-bang thrust deflector on the tail section. Complete verification of the controller design was not possible due to the large computer resources that would have been required, but the results do show the control trends that are expected. The application of wing tip and yaw thrusters to other air cushion aircraft should provide comparable results. Also, these thrusters could be used on Vertical or Short Takeoff and Landing (V/STOL) aircraft because these aircraft also have marginal stability and require control enhancement in the low speed range.

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Appendix A

Graphs of Aerodynamic Coefficients

- Fig. A-1 Lift Coefficient Versus Angle of Attack
- Fig. A-2 Pitching Moment Coefficient Versus Angle of Attack
- Fig. A-3 Drag Coefficient Versus Angle of Attack
- Fig. A-4 Side Force Coefficient Versus Sideslip Angle
- Fig. A-5 Side Force Coefficient Versus Sideslip Angle For Angle of Attack = 0.1 Deg
- Fig. A-6 Roll Moment Coefficient Versus Sideslip Angle For Angle of Attack = 2.2 Deg
- Fig. A-7 Roll Moment Coefficient Versus Sideslip Angle For Angle of Attack = 4.3 Deg
- Fig. A-8 Roll Moment Coefficient Versus Sideslip Angle For Angle of Attack = 6.4 Deg
- Fig. A-9 Yaw Moment Coefficient Versus Sideslip Angle For Angle of Attack = 0.1 Deg
- Fig. A-10 Yaw Moment Coefficient Versus Sideslip Angle For Angle of Attack = 2.2 Deg
- Fig. A-11 Yaw Moment Coefficient Versus Sideslip Angle For Angle of Attack = 4.3 Deg
- Fig. A-12 Yaw Moment Coefficient Versus Sideslip Angle For Angle of Attack = 6.4 Deg

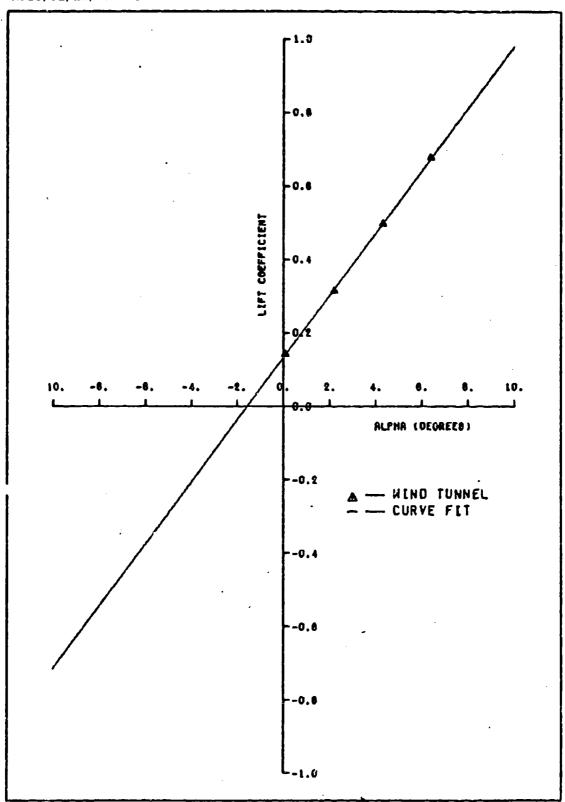


FIG. A-1 LIFT COEFFICIENT VERSUS ANGLE OF ATTACK

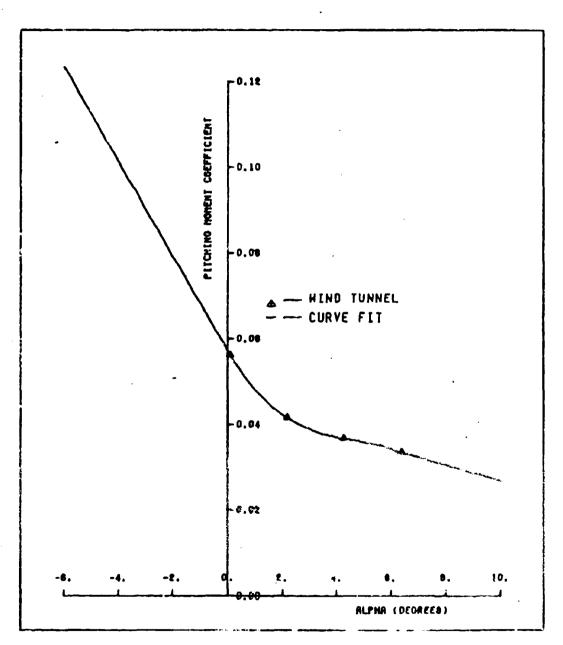


FIG. A-2 PITCH TO OMENT COE TO JEN VERSUS BAGLE OF ATTHE

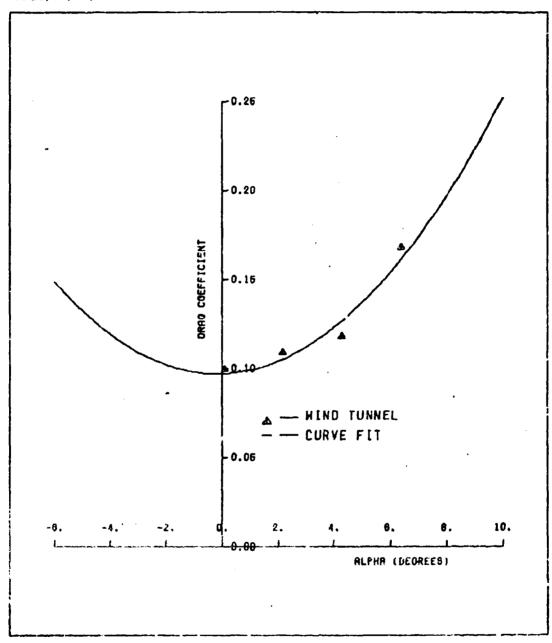


FIG. A-3 DRAG COEFFICIENT VERSUS ANGLE OF ATTACK

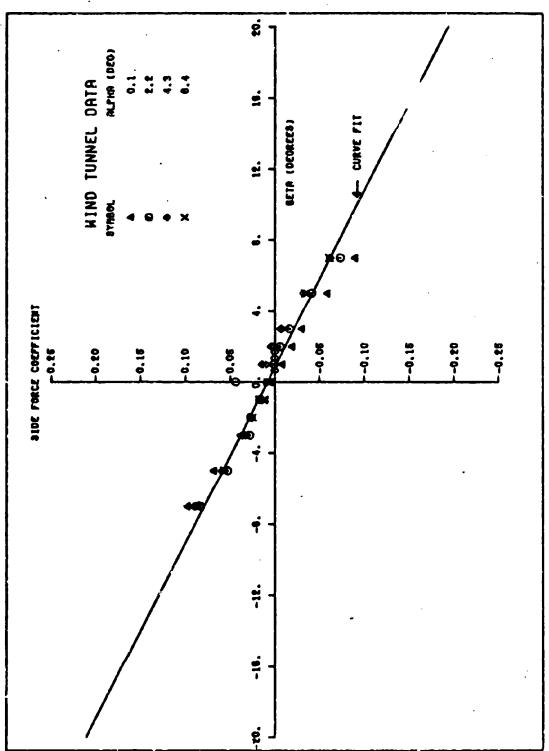


FIG. A-4 SIDE FURCE COEFFICIENT VERSUS SIDESLIP ANGLE

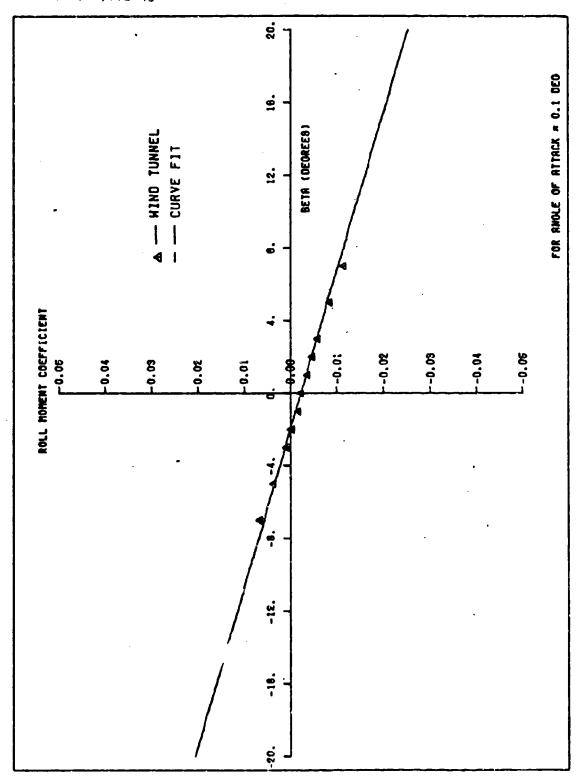


FIG. A-5 ROLL MOMENT COEFFICIENT VERSUS SIDESLIP ANGLE

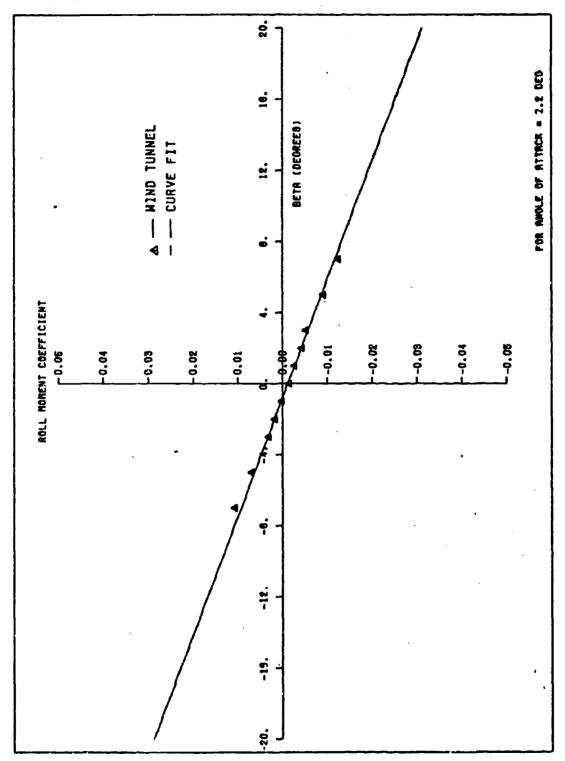


FIG. A-6 ROLL MOMENT COEFFICIENT VERSUS SIDESLIP ANGLE

FIG. A-7 ROLL MOMENT COEFFICIENT VERSUS SIDESLIP ANGLE

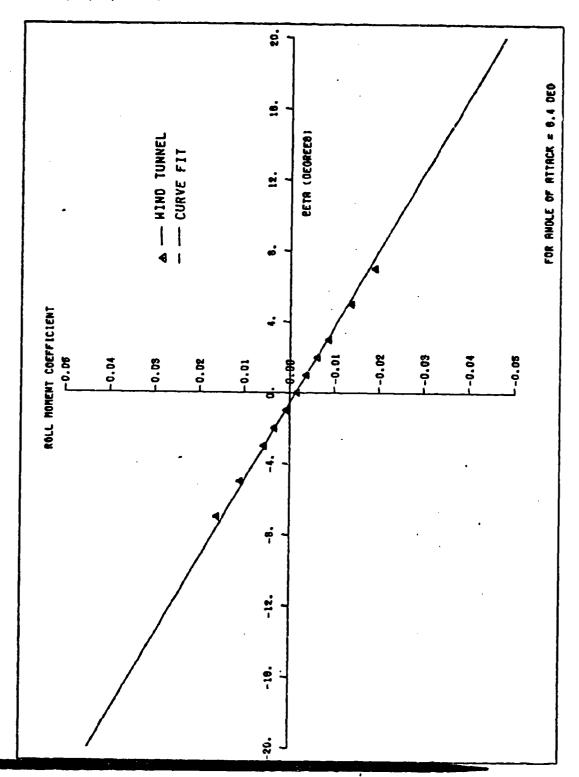


FIG. A-8 ROLL MOMENT COEFFICIENT VERSUS SIDESLIP ANGLE

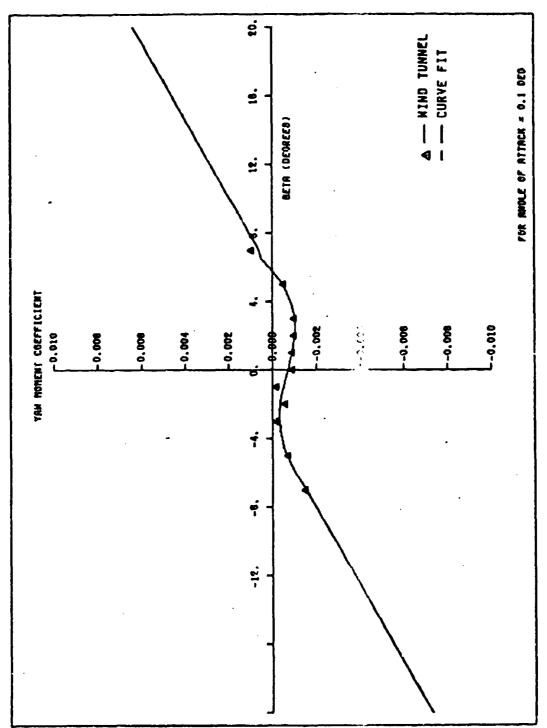


FIG. A-9 YAW MOMENT COEFFICIENT VERSUS SIDESLIP ANGLE

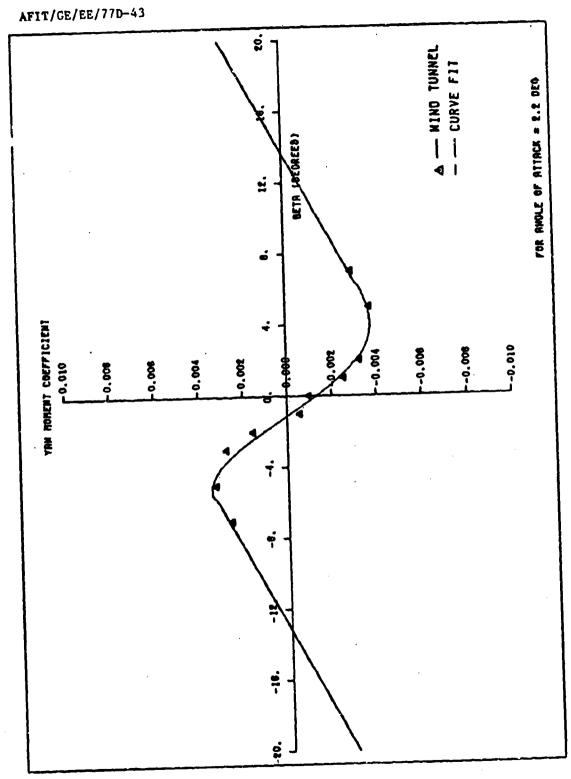


FIG. A-10 YAM MOMENT COEFFICIENT VERSUS SIDESLIP ANGLE

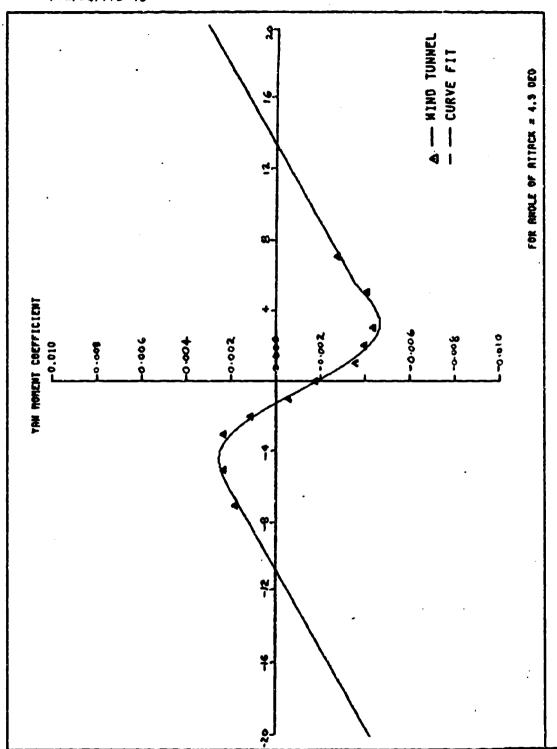


FIG. A-11 YAW MOMENT COEFFICIENT VERSUS SIDESLIP ANGLE

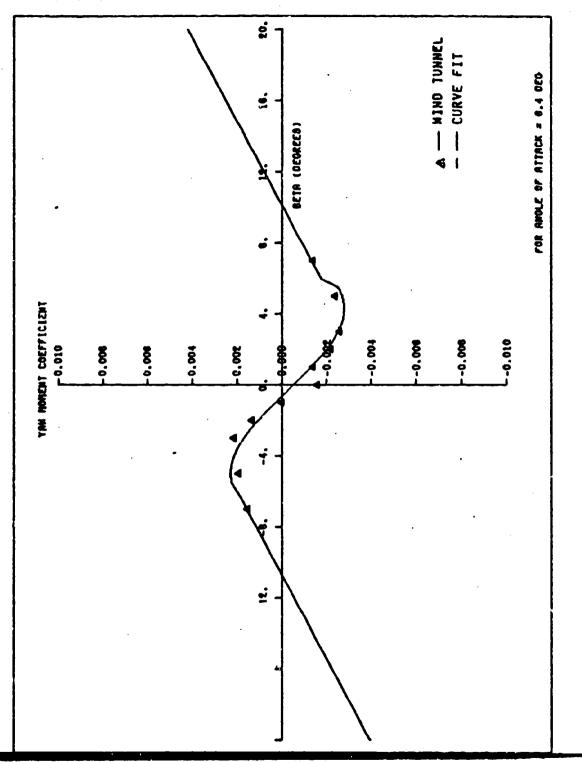


FIG. A-12 YAW MOMENT COEFFICIENT VERSUS SIDESLIP ANGLE

Appendix B

Computer Program Listing

	DESCR					CONTO	CLLEON	• •		
ADD S	TATES=	POLF M	PLATE	1, PCHF	H	٠. مَ م		ue	D.AH	HY I . SH.
H DCA	ARATE I	: 42 m	CKK	PAT.	EC.	. 0.6	C.FF.GG	TE	U:#n; M;	u111341
 -			joy,				. CA		GP. CPA.CT	C, PHA,
		CPC.C	or,ct	A, DPC,	HDC _		AAT,	_ AIF,		APC, APA,
	APT			. •						
	ARAMET!				TV 0	2 74.	SKTFH.		- Moris	.8E SE.
EDÓ A	Se at 9a	195.L	34 . L P	.LPS.L	0.0	5. 1A7.	D2131.A	1 51.42	S1 . SI_S1	
Ox1	51.BET	SILLI	151.L	? I S 1 • F	1151	·32IS1.		HEDOT,T		VTKSZ.
VCH	IS2.ACH	SZ.FY	ST.T	2 51.	x ST	. YMDS			FM.NO.HO	
			5,402	, NP 5 , C	: 22 F M				KFM,VPLFM CS2.ACCS2	
_ **	NE.DVC	rn, . NG . N	35 . DP	FH.01	CEM .	414324 A1470	TKCH.AT	KAT-ATK	CHC.TIKAT	C. OCHAT
				TK, PI						
LOCAT	TON: 65									
	AN STA			وعمادو						
C	ALL A					ne au 2	E 1 E - E 1 E	10 CALT	= ALTS0 \$9	T.RE AU
·	_ VS AV _ En≈Rn							SAL=AL		5 - 75 AV
			74532		, , - • ,					
	VH AV	=40. *	COSCY	HSO-F	ATOAS	N)				
	BRESS	*R10I	AN SA	4 = 4 L + 4	ADIA	N				
C	CALCU						. 55=76	. SE'HO=	23.77E-4	49219.
	STATE	-10~1 =13.	SXTAI	1=3, ; L=10.	SCLA'	1. BU 12:3.05	SSFINE	7.2 SXF	IN=10. SC	LADR=1.5
	CLQR=	12. C	41.50	571IL4	XIII	L) / (C <u>*</u> S)			
							((C++2)	•\$)		
	CYPR=									
_	CYPR=				(111/	(2-8)				
	CL0=	13 35	_0°E = .	352 5	CLÁĒI	02.0857	STL=.1	56 SCLA	LR=4.91	
	GOEFF	e . 1	115-41	T 301	. 4 I L =				· 21/57.3.	
	IFIAL	T.GT.	22.16	FFF=) .					
12	CL=1C	LD+CL	SUD A	しゃらりだり	F) + C	05(BR)	0.)**2)			
	CCALR				65-4	- 126241	0,7,			•
	PCAMO	z-2.*	CLATO	• (x T 4)	[44.2	i * stáll	*SLOPE /	((C++2)	•s)	
	CNRR=	-2. + C	LAFRE	SF IN .	(ALIA)	-+2)/(5	(9**2)	1-CC*RO	*8/(8. *VT)
				ZF:H+9	FIN+	XFIN/(S	*B**2)-	CLALR*P	0*C/(8.*V	T) + C DALR/6.
	CLPRE	- ULAL	15000	C 7 N F V I	Y-(# 7)	ETWZ (C	P++21+6	0+C1 +AZ	(8.*VT)	 -
	CLOAR									·
	CLELR	2(5.4	3:-5-	ELE**	2-2.E	-5 . EL .	4.73E+3			
									7) *CO5 (BR	<u> </u>
•							LE-1.25	-2) -57.	3	
	CAVA=			0.1 GC 6E+2		÷ 1 0				
210	IF IA?				то :	200				
	CPOLL	*-SIN	(32)*	2450						
	_CY:-S									
200				T) 17(3.1160	TO 180			
•	1F ((A	L.Gi.	3.) . A:	ND. (AI	LT	5,1160	TO 190			
	IFIAL	•GE • 5	.160	10 195	5					
	NGLE C									
170	CD=CC	1 • { 2 •	75£-6	A854	() • •	3+2-25	- 4. ARS	8E) • • 2-	6. 37E-4.A	BS (8E)) * COS
	X(OR)	\$10"1).) G(n ta	2000				
- · ·				10						
_	18195	.65.7	.1 GO	TO 4)					
•				• • 5 • 1	255-	7• 3E• • 4	+1.06c-	5-8[3	+1.98E-6*	06 • • 2 - 2 • 18-
	X4*BE-	7.03E	-4							

•	
CY=-4,39E-5*9E**3+1.68E-5*3E**2-1.33E-2*8E+2.56E-3	
CROLL=-1.1455-3-85-2.3556-3	
GO TC 2000	
36 GVAH=++42E-49E+1-54E-3	
1F(A95(36).GT.30.) GO TO 2000	
CY=-4.39E-3*3:**3+1.68E-5*3:**Z-1.33F-2*BE+2.56E-3	_
CPOLL**1.1*8E*3*9E*2.355=3	
GO TO 2000	
1F(ABS(96).ST.30.) SO TO 2000	
	—
CROLL=-1.1455-3.9E-2.3555-3	
· 60 TO 2000	
G ANGLE OF ATTACK IS LESS THAN 3.0	
180 CD=CC1+(-5.142-6-495(9E)+-3+3.03E-4-ABS(BE)+-2-2.37E-4-ABS(BE)) +C	
(9e)20K	
IF(A2S(9E).GE.60.) GO TO 2000	
IF(85.LT7.) GO TO 50	_
IF(92.62.7.) GO TO 60	
CYAM=-7.0E-9-95-5-1.075-6-3E-4-1.05E-5-8E-4-3+7.42E-5-8E-7-1.13E	
Xe348[e1,34]e3	
CY=3.03=-7*3=*5+2.14E-6*8E**4=9 .83E-5*8E**3-1.64E-4*9E**2-7.21E- X3*8=*3.16=3	
CPOLL*-1.5015-3*85-1;265-3	
60 TO 2000	
50 CYAHE-, 32-4-95+5, 672-3	
IF(A2S(3E).GT.3).) GO TO 2000	_
CY=3.03=-7-355-2.14E-6-9E-04-9 .83E-5-8E-0-3-1.64E-4-9E-02-7.21E-	
X3*8E+8.16E+3	
C FOLL = - 1.531 = - 3 - 9E - 1.26 = - 3	_
GO TO 2000	
60 CYAN* 35 95 - 5. 895 - 3	
1F(A9S(3±).ST.30.) GO TO 2000	
CY#3. 035-7°35°43+2.145-698500-9 .835-5986003-1.645-498602-7.216-	
X3°9E+0.16E+3	
GROLL=-1.5):[-3*8[-1.26]-3 GO TO 2000	_
C ANGLE OF ATTACK IS LESS THAN 5.3	
190 CD-CD1-(-4.12=-5-A9S(8E)3-2.5E-4-ABS(8E)2-2.34E-4-ABS(8E))-COS	_
X(BR)	
1F(A95(92).GE.50.) GO TO 2000	_
IF(95.LT.+7.) GO TO 70	
IF(05.GE.7.) GO TO 80	_
CYAH=-4.14=-7-8=-5-7-875-7-85-04-4.36E-5-85-0-3-6.546-5-865-02-1.47	
x6+3*95-1.832+3	
CY=2,93=-6*3=**3+3,72E-7*B=**4-2,835-4*BE**3-1,9E-5*BE**2 -4,86E-3	_
X*86+1.364-?	
GROLL=-1.9775-3*95-1.5555-3	_
70 CYAH=4.3E-4*9E+4.82E-3	
JF (ABS (96) . GT. 30.) GO TO 2000	
CY=2.936-6*96**5+3.726-7*86**4-2.836-4*06**3-1.96-5*86**2 -4.066-3	
X+9E+1.36E-2	_
CPOLL*-1.9*75-3*95-1.5555-3	
60 TC 2000	
80 GYAH=4.5E-4*3E-5.05E-3	
IF(495(95),GT.30.) GO TO 2000	
CY02,93=-6*3:0003,72E-7*9=004-2.83E-4*3E**3-1.9E-5*8E**2 -4.06E-3	
X+8E+1,36E-2	
GPOLL =-1.977E-3*8E-1.555E-3	
GO TO 2000	
C ANGLE OF ATTACK IS GREATER THAN 5. 195 CD=CD1+(2,15=-5*ANS(NE)**3+1.51=-4*ABS(NE)**2+1.24E-3*ABS(BE))*GOS	
195 CURCUIFICATO DE DE MISTE DE LA COLLEGE D	
1F(A9S(BE).SE.60.) 50 TO 2000	_
1F(0E.LT7.) GO TO 90	

```
IF(05.GE.7.) GO TO 100
CYAM=1.28E-5*9E**3+1.23E-5*35**2-8.21E-4*8E-5.33E+4
CY-1.76E-6*3E**5-1 .91E-7*9E**4-1.8E-4*9E**3+2.72E-5*8E**2-5.82E-3
          X . RE . 1 . 04E - 2
            CROLL - 2. 3925 - 3 95 - 1. 445 - 3
            GO TO 2000
            CYAH ... 24 E -4 - 8E + . 0045
            IF(A35(32),57,30.) GO TO 2000
GY=1.76E-6-3E**5-1 .916-7-9E**4-1.6E-4-3E**3-2.72E-5-8E**2-5.82E-3
          X+8E+1.04E-2
            CFOLL = 2. 3026-3-82-1.4451-3
           GC TO 2000
CYAH#4.24E-4-9E-4.3E-3
            IF(ABS(98),CT.30.) GO TO 2000
CY=1.768-6*98**5-1 .918-7*38**4-1.88-4*98**3+2.728-5*88**2-5.828-3
          X+95+1.04E-2
            CFOLL #-2. 3025-3-8E-1.445E-3
2000 CONTINUE
            DERIVATION OF DIMENTIONAL DERIVATIVES (STABILIT Y AXIS)
            ZMOS=- 240 - 5 - 674. - CL AOR
            ZOS=-OS/VT+C/Z.+CLQR
           ZCELS=-05°CLELR
HHOS=9H0*5°C**2*CH40R/4.
HOS=05/VI*0**2*CH0R/2.
           HOELS=GS*CHELR*10.
            YDR=35+ CY
NCR=05+3+CYAW
            LC9+CS+3+CROLL
            YRS= 9HC*S*3/4. *CYRR
            YPS+RHO+S+3/4.+CYPR
            NPS=05/VT+3**2/4. *CHRR
           NPS=CS/VT+3+42/4. *CNPP
LPS+CS/VT+3++2*CLRR/2.
            LPS+05/VT+3++2+3LP3/2.
            LOELS=OS*E*CLAIL
            XOS=0. SXWDS=0. SHOELS=0.
            DERIVATION OF DIMENTIONAL DERIVATIVES (800Y AXIS FROM STABILITY AXIS)
            X0-CL-05-SIN(AR)-CD-05-COS(AR)
            Z0=+CL*05*305 (AR) -CD*05*SIN (AR)
            MO=CH+CS+C
           #U=(N*CS*C)

XHD=(YHDS*)OS(AR)**2-ZHDS*SIN(AR)*COS(AR))*COS(BR)

ZAD=(ZHDS*)OS(AR)**2+XHDS*SIN(AR)**COS(AR))*COS(BR)

#AD="HDS*C)S(AR)**COS(DR)

YP=YFS*COS(AR)**YFS*SIN(AR)
            YR#YOS COS (1R) +YPS SIN(4R)
            XDEV-ZOELS*SIN(AR)*COS(3R)
            XC= (XOS*CC3(A2)-705*S19(AR))*COS(BR)
            ZQ= (705°C03(4P) +X05*SIH(AR)) +C05(BR)
           Z0E+ZDELS+305 (AR1+305 (9R)
           LP=(LPS-CO3(AR) -- 2-(LR3+HPS) -SIN(AR) -COS(AR) +NRS-SIN(AR) -- 2) -COS(B
         XR)
          LDA=(LDELS*COS(4R)+NOELS*SIN(AR))*COS(DR)
LR=(LRS*COS(AR)**2-(NPS-LPS)*SIN(AR)*COS(AR)+NPS*SIN(AR)**2)*COS(B
           NP+ (NPS*COS(4R) ** 2 - (NPS-LPS) *SIN(AR) *COS(AR) -LRS*SIN(AR) ** 2) *COS(B
          MR=(MRS+CO3(AR)++2+(LPS+MPS)+SIN(AR)+COS(AR)+LPS+SIN(AR)++2)+COS(B
   XR)
                          HONNOS SHOENDELS
          CONTINUE
            #0 LO=#0 $40ELO=#0E 170 LO=ZO $740LO=ZAO $ZQ LO=ZQ $ZDELO=ZOE
           NO LOSTO SANDLOSTOS THE LOSTO SALECTION SALECTION OF SALE
           NP LOOMP THE LOOMS BOS AVEOS SCHELOFFLE TALTSOFALT TAL AVEAL
BE AVEOT TEO AVEFO SEC AVEPO SVE AVEVE SOO AVEOD INSPESS
         LURCOSCOR IVOPLOSTOR INDELDENOR
```

LOCA	TION#142,EN	•		-,
FORT	RAN STATEMENTS	• .	•	
		8.47°TH EN-1.84E-	2*TH EN**2+9.23E	-6-TH EN-+3-1.67E-9-
	XTH SHOP4	* * * * * * * * * * * * * * * * * * * *		
10		.PSHF4.PTKF4.PPL6	H. VTKS2.PENEH. OF	NFH. OFXFH. IPPF
		VOSEM, RHOFM, DVK		DVCFM.SKTFM.
				U SO.M SO.AL AV.P
		149.22H. 44.02	TEM, HYI.	OP1,R1 TK,P2 TK,L1
• •	XIK.LZ TK.PHIT			SD.XZ IT 3.OPTFH.OTC
	YEA OTAEM ATEC	U ATVAT ATVOUC AT	WATE BENAT U ED	Dusty Lites Lates &
	XSHAPE!	4+++×4-+++	KAIC GCHAI IA ZON	PH2TK.L1151.L2151.1
	X 5 7 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4		50 454444444	,,,,,,,,,,
_6100	764-061-60-108		EQ	
		AV) *485(PO AV) / (2	. "UMAX"8.16E-3)	
				·
		.05°xamu =NCDx		
		.AND.(PO AV.GT.O.		
		.A43.{PO AV.LT.O.		
	IF((A35(RO_5)).:0.9.0).AND.(43	S(F0 AV).EC.0.0)) TXCON=0.
C+++	• • • • • • • • • • • • • • • •	* * * * * * * * * * * * * * * * * * *	******	• • • • • • • • • • • • • • • • • • • •
C+++	• • • • • • • • • • • • • • • • • • • •	YAM CONTROLLER	******	
	UYTMAX=TH EN/	23.		
	SIEC=-0.30 *Y)	SD-XZ IT 1		
	SYTX=YLHSO-SI	EO- P SO- 195 (4 5	D1 + 18 3. 15 /UYTHAK	
	IFISYTX, GT. 0.	TZCOM=-UYTHAX410		•
		TECON = UYTHAX -10		
		1.AHD, (F SC. ST.		6×410.
	TELISTIN	1.00 - 1.CHA.C	1. INTECNALIST	AY • 1 0 -
	TEACHARD TO	SIEGIAND. (F SO	76 0 11 T7CON=0	-^ 100
CTTT		•• · · · • • •		
		4 DC) 264*(VA OC)		
		.O.) TYCOH=-UMAX-1		
		O.) TYCON= UHAX*1		
		3. G.) . ANC. (QQ AV.		
		3.0.).AND.(QC 4V.		
,	IF((495(PITSO).E0.0.0).AND.(AB	S(00 AV).EG.0.0)) TYCON=0.
ينبيع		***********		
		74353=TYCO4	3=TZCUN \$FZ2\$3==1	FY ST STX2S3=TX ST
	TY253=T2 ST			
LOCAT	TON=12.LO,14PU	TS=AV.S3.MC_1(X=E	LE)	
		TS=AV.LO.S3.HC 2(
LOCAT	U9VI.C2.7E=401	75=L7.LD		
	RAN STATEMENTS			
	**************************************	1455 -1 55-	•	
		SD-0.1 33 (PITS	0-0-1	
	X1 TF=ELEC			
LOCAL	110N=149.TF			
	101=147.11 7.1	1011TC=TE		
		1PUTS=1F.17 7.11		
		45012=16+T1 1+T1	0	
PORIF	STATE YEARS			
		10.) X4 HC 1=10.	_	
		-15.) X4 40 1e-1	^{>} •	
	10A=155,IT 3.IP			
	ION=5:.IT 3.INF			
	13N=39 .IT 1.It	(X = 0 Y) 0 2 × 3		
FOPTE	CAN STATEMENTS			
	AILC= .196 * (P	\$0-0.) *. 42*(30)	53-0-1+.2*R SD	
	X1 TF Z=AILC			
LOCAT	1 31,845=4CI			
	TON= 245.11 3.14	IPUTS=TF 2		
		PUIS=18 2,11 9.1	T10	
	AN STATEMENTS		- - -	
		8. 1 X4 MC 2:5.		
		-A. 1 14 4C Z=-8	_	
16.01	10N=254.111).I		• -	
ENO 5	**************************************	16313400 6	•	

																7			
FORTR	AN STA	TEME	NTS																
. •	SUPRO				.oc	4 . P1	14. P	31 . V	14. PF	N.01	N.O	FY.		IPP.	055	PP	N.VC	S.R	
	1 HO . DV																		
											,,,							_,0	
	X . W . AL							TEN						TK.					
	x2 TK,	PHII	ĸ,		Т×	ST.	· 4 S	T.TZ	51.5	IE.	CG.	QPTF	Y.0	TCFM	.ar	AFM	, ATC	52.	
	XATAS2	.430	5 ? .	AACS	2 - 9	CHA.	v .	242TI	(.L1I	\$1.6	215	1.19	HAP	E)					
	REAL			MAS				1151											
															٠,				
	DIMEN																		L
	X.05LS	C (32		ILAZ	E (3	2),	, KCI	SE (3)	?),?	015	(32) + I	ISGS	E (35	•	VTI	51(3	2 1	
	X.4CIS	1 (32		YGHC	L (3	2).	ACF	52 (5)	2) . 4	TIS	2132) , F	283	2 (3 2		ATR	52(3	2)	
	X . XCHS																		
	XY0(13							••••				- • •			• • • •	•		• •	
	ATAG							.0.0	17453	2/									
	CTIPE	* . 0 (103_		\$ T I	*1C = 1	l												
C	AIP C	USH	ON	LAND	ING	SY	STEM	E & O!	RAP							_			
=	MSS=7	7.3			= 4	100	C = 1 .	- 50	F=. 9	SNS	PET	2 51	(CD =	٥.		3.0	C <u>* * 1</u>	. 17	
														17 \$				SE.	
	GG= 1	• 7		∍Ç.	3 - A	1 - 61	117.	J			12	> 30	/- • <u>-</u>			777			
	£= , 524	SL:	• L.	. 2 H I	1 11	•.9	_3 <u>M</u> <u>X</u>	<u>. 9, 31</u>	1427.	2.34	iŭ= 2	. 4		2H**	<u>, s s</u>	3_3	LXBU	<u>. 84</u>	
		- (;G>=	.5 \$	GEC	*. 1		50) × X =	1.17	7 ST:	EM#7	70.						
	THEDO						T = - W												
	MASS=			~ ~ ·.'.		\$70	PAT	PETE							_				
			.,,	46-7					150. T	Dec 1			40 * 6	- 140	007	•			
	· ·	1						<u>H</u> E., \$1				•กับ	15 I A	- 1 77 51	naī				
				CTZM	a = H	20.			2 6	PLH	PPL								
C_DAT	A _ACQU	ISI	MCI																
	VPLH:	. 313	5 5 V	FANE	. 46	8													
	VPL=V				• -									•					
	00 10																		
	DELTA	(I) 3	0.0																
100	CONTI	NUE					•												
	_RH0 = 1	. 241	114	50.0	. TE	MPAT	1)												
	HY=4Y			<u> </u>															
				-	T T	S D		NC 91	ATTE	O M	TCH	•							
9 "A	NIPUN	1701		-10	' - <u>+</u>	٠. ح	-/			·									
	MYEAM	IAF1 I								-									
	CALL				<u> </u>	۶۰۲	tĸ,	<u> </u>	Co.FH1	TK	<u>. 1</u> _'.	K + L 4	2_ ! K	<u>, HY</u> ,	115	لو يا .	<u> </u>		
					?1 <u>K</u>	۶.۶	tĸ,	<u> </u>	(,FHI	IK,	.1	K+, C4	2_ ! K	<u>, HY</u> •	<u>4,E</u>	. <u>L</u> ,	<u> </u>		
	CALL Ishap	E×IS	HTK						(<u>, FHJ</u>	<u> </u>	.1'	K+,U4	2 T.K.	<u>, н</u> ү ,	<u>4,E</u>	<u>. L p</u>	<u> </u>		
	_CALL ISHAP _1f(IS	HAPE	HTK						(,,F <u>HJ</u>	<u> </u>	.1	<u>K</u> , L 4	- IK	<u>, HY</u> •	<u>4,E</u>	. <u>L</u> , <u>l</u>			
	CALL ISHAP IF(IS ICLFM	E=15 H428 '=0	. 10	<u>. 01</u>	60	_TC	199		-										
	CALL ISHAR IF(IS ICLFM CALL	E=15 H428 '=0 SE()	HTK • 10 TYS	<u>. 0)</u> E.9I	<u>60</u> SE	TC	19 <u>9</u> 55.	zsxș!	-									2 1	
	CALL ISHAP IF(IS ICLFM CALL IK.PH2	E = 15 HAPE '=0 SE()	HTK - 10 TYS 12 IS	. <u>0)</u> E.9I 1.LS	60 SE	TC • DY	139 SE.	zexs!	, ×C>	SE,	ŽELS	E , XC	ŢŞĘ	. ZCI	SĘ.	1CL	FH.R		
	CALL ISHAP IF(IS ICLFM CALL IK.PHZ CALL	E = 15 HAPE '=0 SE() SE() SI()	145 1215 215	.0) E.9I 1.LS	55 .H.	. Dy	139 SE. ISG S1,	ZSXS! SE) SI S	, xC>	SE,(SIXIS	£,X0	IŞE	.ZCI	S	ICL	FH.R	i i S	
	CALL ISHAP IF(IS ICLFM CALL IK.PH2	E = 15 HAPE '=0 SE() SE() SI()	145 1215 215	.0) E.9I 1.LS	55 .H.	. Dy	139 SE. ISG S1,	ZSXS! SE) SI S	, xC>	SE,(SIXIS	£,X0	IŞE	.ZCI	S	ICL	FH.R	i i S	
	CALL ISHAP IF(IS ICLFF CALL IK,PH2 CALL 11,P21	= 15 = 0 = 0 5 = () 5 = () 5 = ()	142 142 15 15 15 15 15 15 15 15 15 15 15 15 15	.0) E.9I 1.LS 1.A1	55 .H. S1 21K	.Dy	139 SE. ISG S1, IK.	zoxos Se) Si S	, xC;	SE, C	SIXIS	£,X0	IŞE	.ZCI	S	ICL	FH.R	i i S	
	CALL ISHAP IF(IS ICLEM CALL IK.PM2 CALL II.PZI XZ TK.	#498 #0 \$10 \$10 \$10 \$10 \$10	TYS 121S 121S 111S 111S	.0) E.SI 1.LS 1.A1 1.0H	55 .M. 51 21K	TC • DY • O. • A 2 • • 2 • • 2	139 SE. ISG S1, TK.	ZCXS! SI S OX S:	1,01 1,01 1,05	SE,(S1.(SE.)	OXIS OXIS	£,XQ 1,9: 1 T:	ISE IS1 K, PH	.ZCI	SE.	ICL	FH.R	i i S	
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	CALL ISHAP IF(IS ICLFM CALL IK.PM2 CALL II.P2I X2 TK. FPLM=	F#15 HAPE ************************************	TYS 21S 21S 21S NIS 52.5 23-	.0) E.9I 1.LS 1.A1 1.0H ,A.I 3.17	50 .M. 51 21K	TC •DY ••0 •42 •22 •4,V	199 SE. ISG S1, TK. IS1	70X5 52) 51 S 0X S: -ACI:	1,01 1,01 1,05	SE,(S1.(SE.)	OXIS OXIS	£,XQ 1,9: 1 T:	ISE IS1 K, PH	.ZCI	SE.	ICL	FH.R	i i S	
	CALL ISHAP IF(IS ICLFM CALL IK.PM2 CALL II.PZI XZ TK. FPLM= PFAN= UT PRE	F#15 HAPE #0 SE() S1() S1() S1() S1() S1() S1() S1() S1	TYS 215 215 215 315 315 23-	.0) E.SI 1.LS 1.A1 1.04 1.04 3.17	50 SE S1 21K N.	TC • DY • • O • • A 2 • • P 2 • P 6 • R 6:	139 SE. ISG S1, TK. IS1	75X55 55 S 9X S 9X S 9X S	1, CI 1, EE 51, LS	SE, (SE,) SE,)	2. 0 2. x1 S 2. x1 S	£, XC 1, 9: 1 T: 86E-	ISE (, PH	.ZCI	SE.	ICL	FH.R	i i S	
	CALL ISHAP IF(IS ICLFP CALL IK-PH2 CALL IX-PFI FFIANE UT PRE	5 × 15 5 × 10 5 × 10	TYS 21S 21S 21S 21S 21S 21S 21S 21S 21S 21	.0) E.SI 1.LS 1.A1 1.0H .A.I 3.17	50 SE S1K 21K .N.	TC • DY • A 2 • P 2 • P 6 • R 6 • UT I • A NC	139 SE. ISG S1, TK. IS1 1+5.	70X5(52) 51 S 0X S(+40I(54E+	1. CI 1. EE 51. LS	SE, (SE,)	0.5-0	£, X(1, 9; 1, T) 86E-	ISE (,PH	.ZCI	SE.	ICL	FH.R	i i S	
	CALL ISHAP IF(IS ICLFF CALL IK.PH2 CALL II.PZI II.PZI FPLM: FPLM: IF(IP IF(IP	5 × 15 5 × 15 5 × 16 5 × 16	TYS 21S 21S 21S 31S 21S 21S 21S 21S 21S 21S 21S 21S 21S 2	.0) E.9E 1.LS 1.A1 1.0H .4.E 3.17 NO 0	SE .M	TC • DY • A 2 • P 2 • R F: • R F: • A 10 • A 2 • A 3 • A 4 • A 4 • A 5 • A 6 • A 6 • A 7 • A 7 • A 8 • A 8 • A 9 • A	139 SE., ISG SI, TK., ISI 1.5.	75X5: 52) 51 S 0X S: +401: 53E-	1. CI 1. EE 51. LS 50 RPH	SE, (SE,) SE,) (SE,) (SE,) (SE,)	00 GO	1, 9: 1 Ti 86E- TO	ISE (,PH -10*	.ZCI	SE.	ICL	FH.R	i i S	
	CALL ISHAP IF(IS ICLFP CALL IK-PH2 CALL IX-PFI FFIANE UT PRE	5 × 15 5 × 15 5 × 16 5 × 16	TYS 21S 21S 21S 31S 21S 21S 21S 21S 21S 21S 21S 21S 21S 2	.0) E.9E 1.LS 1.A1 1.0H .4.E 3.17 NO 0	SE .M	TC • DY • A 2 • P 2 • R F: • R F: • A 10 • A 2 • A 3 • A 4 • A 4 • A 5 • A 6 • A 6 • A 7 • A 7 • A 8 • A 8 • A 9 • A	139 SE., ISG SI, TK., ISI 1.5.	75X5: 52) 51 S 0X S: +401: 53E-	1. CI 1. EE 51. LS 50 RPH	SE, (SE,) SE,) (SE,) (SE,) (SE,)	00 GO	1, 9: 1 Ti 86E- TO	ISE (,PH -10*	.ZCI	SE.	ICL	FH.R	i i S	
	CALL ISMAP IF(IS ICLEP CALL ICALL ICALL IL-PZI XZ TK. PFAN: PFAN: UT P(IS IF(IS	# 15 # 40 # 50 # 51 # 51 # 51 # 51 # 51 # 51 # 52 # 60 # 60	TYS 21S 21S 21S 21S 21S 21S 21S 21S 21S 21	.0) E.BI 1.LS 1.A1 1.0H .4.E 3.17 NO 0 1937 2075 E217	SE .M	TC • DY • N • D • A 2 • P 2 • P 7 • R F: • R F: • A N D • A N D • A N D • A N D	139 SE. ISG SI. IK. ISI 1.5. LOW	75X51 52) 51 S 0X S +4011 53E-1	1. CI 1. EE 51. LS 50 RPH	SE,(SE,) SE,) (SE,) (SE,) (SE,) (SE,)	0 00 00 00 00 00 00	1.9: 1. Ti 86E- TO TO	ISE IS1 (,PH -10*	.ZCI	SE.	ICL	FH.R	i i S	
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	CALL ISHAP ICLEP CALL ICLEP ICLE	# 1 2 5	5HTK: 1215 1745 1745 1745 1745 1745 1745 1745 17	.0) E.BES 1.LA 1.A 1.A 1.A 1.A 1.A 1.A 1.A 1.	50 SE. M. SIK. SIK. SIK. SIK. SIK. SIK. SIK. SIK.	TC .DY .DY .AZ .PZ .PZ .PX	139 SEG . ISG	ZCXS: SC) SC) SC) SC) SC) SC) SC) SC) SC) SC)	1. CI 1. EE 51. LS 1. 207 1. 221 1. 2. 235 1. 2. 44 1. 2. 62 1. 63 1. 64 1. 64	SE, (SE, (SE,) SE, (SE,) SE, SE,) SE, SE, SE, SE, SE, SE, SE, SE, SE, SE,	2130 2130 2130 2130 2130 2130 2130 2130	1.9: 1.7: 566E- 10 10 10 10 10 10	87 88 89 90 91 92 93 94 95	.ZCI	SE.	ICL	FH.R	i i S	
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	CALL ISMISS	## 13	## TYSS	.0) E. SI 1.LA1 1.A1 1.A2 1.A3	GO SE M. SIK. SIK. SIK. SIK. SIK. SIK. SIK. SIK	TC .DV .DDV .DAZ .PZ .PZ .PZ .PV .PR .RR .RR .RR .RR .RR .RR .RR .RR .RR	139 SE	ZSXS! SSI S 9A S! *ACI! ************************************	1.01 1.01 1.05 1.120 1.20 1.21 1.21 1.20 1.20 1.20 1.2	S1.((SE,)) S1.((SE,)) (SE,))	21 20 20 20 20 20 20 20 20 20 20 20 20 20	10 10 10 10 10 10 10 10 10 10 10 10 10 1	87 88 89 90 91 93 93 95	.ZCI	SE.	ICL	FH.R	i i S	
	CALL ISMAP IF(IS) ICLEP CALL IK.PH2 IX.PZI FPLMMM FPLMMM IF(I	# 13	## TYSS	.0) E.BES 1.A1 1.A. T 1.A.	GO SE ST	TC .DY DY A	1399 SE-6 SI-6 SI-7 SI-7 SI-7 SI-7 SI-7 SI-7 SI-7 SI-7	75X5 557 557 557 538- 4.LT 4.LT 4.LT 4.LT 4.LT 4.LT	1. CI 1. EE 1. LS 1. LS 1. 207 1. 221 1. 242 1. 242	\$1.6 \$1.6 \$2.7 \$3.11 \$3.11 \$1.7 \$1.7 \$1.7 \$1.7 \$1.7 \$1.7 \$1.7 \$	25 LS 27 LS	10 10 10 10 10 10 10 10 10 10 10 10 10 1	SISE (, PH -10* 87 88 89 91 92 93 94 95 96	.ZCI	SE.	ICL	FH.R	i i S	
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	CALLAR ISHIN	# 13	######################################	.01 E.921.LS 1.451. 1.4.21.	GO SE	TO .P. D.	1399 SE-6 ISG SI-, IS	ZGXS2 S S S S S S S S S S S S S S S S S S	1.01 1.05 1.05 1.05 1.05 1.05 1.05 1.05	S1.(SE,); S1.(SE,); SE,); 3.1; 3.1; 1.1; 9.1; 7.1; 1.1; 1.1; 1.1; 1.1; 1.1; 1.1; 1	25 LS 27 LS	1. e. xxx 1. e.	87 88 89 91 91 92 93 94 95 96 97	.ZCI	SE.	ICL	FH.R	i i S	
	CALL ISMAP I	# 13	######################################	.01 E.921.LS 1.AS 1.AS 1.AS 1.AS 1.AS 1.AS 1.AS 1.A	GO SE. M. 2 TK. 2 TK. 2 TV. 3	TO .P. D.	1399 SE-6 ISG S1-, IS	ZGXS2 S S S S S S S S S S S S S S S S S S	1.01 1.05 1.05 1.05 1.05 1.05 1.05 1.05	S1.(SE,); S1.(SE,); SE,); 3.1; 3.1; 1.1; 9.1; 7.1; 1.1; 1.1; 1.1; 1.1; 1.1; 1.1; 1	25 LS 27 LS	1. e. xxx 1. e.	87 88 89 91 91 92 93 94 95 96 97	.ZCI	SE.	ICL	FH.R	i i S	
	CALLAPS ISHIP ICLEP	# 13	######################################	.01 E.911.LS 1.4L1 1.4.17 NO 07375 20	GO SENTE OF TO SENTE OF THE SEN	TC .DY .D.DP.AZ .P.VP.AZ .P.VP.AZ .P.VP.AZ .P.VP.AZ .P.AZ .P.AZ .AAAAAAAAAAAAAAAAAAA	139 SE. 6.25 SI. 1151 SI. 1455 COPPE (COPPE (CO	75 X S S S S S S S S S S S S S S S S S S	1207 1227 1237 1241 1276 1276 1276 1276 1276 1276 1276 127	S1,6 S1,6 S1,6 S1,6 S2,6 S1,9 S1,9 S1,9 S1,9 S1,9 S1,9 S1,9 S1,9	DELS DX IS DX br>DX IS DX DX DX IS DX IS DX IS DX IS DX IS DX IS DX IS DX IS DX IS DX IS DX DX IS DX DX IS DX DX IS DX DX DX DX DX DX DX DX DX DX DX DX DX DX DX DX D	10 TO	87 88 89 91 92 93 94 95 97 98	.ZCI	SE.	ICL	FH.R	i i S	
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	CALLAPS ISHIP ICLEP	# 13	## ## ## ## ## ## ## ## ## ## ## ## ##	-01 -01 -01 -01 -01 -01 -01 -01 -01 -01	GO SENSIA DE LA COMPANSIA DE L	TO .D.DD.DA.ZPA.Z. VPPPPPPPPP.	139 SE. 6 SI.	ZSXS: SSI SSI SSI SSI SSI SSI SSI SSI SSI SSI	1207 1207 1207 1207 1207 1207 1207 1207	S1.6 SE.7 2. 2. 2. 2. 2. 2. 3. 	DELS DXIS OXIS	1. e. xc. 1. e.	SISE IS1 (*, PH - 10 * 8 * 8 * 8 * 9 * 9 * 9 * 9 * 9 * 9 * 9	.ZCI	SE.	ICL	FH.R	i i S	
	CALLAR ISMAN	# 13	# Y Y Y Y Y Y Y Y Y Y Y Y Y Y Y Y Y Y Y	-01 -01 -01 -01 -01 -01 -01 -01 -01 -01	GO SENSIA 2 1 No. 2 1	TC. VA. 2. V	139 SE. 6 ISG	75X55 53 S S S S S S S S S S S S S S S S S S S	1207 1.01 1.01 1.05 1.05 1.05 1.05 1.05 1.05	S1.(S1.(S1.(S1.)) (S2. (S1.) (S2. (S1.) ((DELS DXIS DXIS -2.0 0 G00	1. 9: 10 TO	87 88 89 91 92 93 94 95 96 97 99 101	.ZCI	SE.	ICL	FH.R	i i S	
	CALLAPS ISHIP ICLEP	# 13	## (201 - 01 - 01 - 01 - 01 - 01 - 01 - 01 -	GO SENTE UT	TO .D.DD.DD.DD.DD.DD.DD.DD.DD.D.D.D.D.D.D.D.D.D.D.D.D.D.D.D.D.D.D.D	1399 SE-6 ISG SI+- IS	75 X S S S S S S S S S S S S S S S S S S	1207 1207 1217 1217 1217 1218 1218 1218 1218 121	S1.((SE.)) S1.((SE.)) SE.)) SE.)) S.)) S.)) S.)) S.)) S.	DELS DXIS -2.0 -2.0 -3 -3 -3 -3 -3 -3 -3 -3 -3 -3 -3 -3 -3	1. 9: 1 T' 86E- 10 TO 10 TO 10 TO 10 TO 10 TO 10 TO	87 88 89 90 91 92 93 94 95 96 97 98 99 101	.ZCI	SE.	ICL	FH.R	i i S	

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Z	PRINT 3	•	• • • • • • • • • • • • • • • • • • • •	••
3	FORMATICOFF LOWER END	OF FAN MAP*)		
	GO TO 199	· · · · · · · · · · · · · · · · · · ·	· · · · · · · · · · · · · · · · · · ·	
4	PRINT 5			
5	FORMATIO OFF UPPER EN	D OF FAN MAP+)		
	GO TO 199			
	CURVE FOR STATIS TIER			
. 85	QFAN=15.06353	- +>FAN+L.345-3	*PFAN**2-1.65E-5	•PFAN
_ :	x••3 \$GO TO 110	4354W-7 465-7	A0544843-1 105-6	•PFAN
. 83	QFAN=15.08339 x++3 1G0 TO 110	#PFAN+3.84E-3	*PFAN**2-1.39E-5	FFAN
	QFAN=11.33154	#PFAN+1.74E-3	*PFAN**2-6.3E-6	*PFAN
•-	X++3 \$GO TO 110			
45	CFAN=10.82129	*PFAN+1.29E-3	*PFAN**Z-4.562-6	*PFAN
	x++3 \$GO TO 110			
8.6	QFAN#9.73 077_		*PFAN**2-2.6E-6	PFAN
	x**3 \$GO TO 110			
87	OFAN=9.97 077	**************************************	*PFAN** 2-2.4E-6	PPFAN
	X+43	A354W. A 845-7	4054H443-7-065-6	*PFAN
60	QFAN*12.3915 X**3 SGD TO 110	PFAN+1.32E-3	*PFAN**2-3.96E-6	-FFAN
89_	QFAN=18.38333	**FAN+ 2. 87E-3	*PFAR**2-7.79E-6	*PFAN
	x • • 3		— 11,57% 8, 2,72,7 8,2	
90	QFAN=15.03,211	#2FAN+1.74E-3	*PFAN**2-4.67E-6	PFAN
	X++3 SG) TO 110			
91	QFAN=12.7313	*PFAN+1.03E-3_	*PFAN**2-2.78E-6	PFAH
	X++3 SGD TO 110			
_92	QFAN=13.78153 X++3 SGD TO 110	**FAN+1.17E-3	*PFAN**2-3.01E-6	PFAN.
	X++3 \$60 TO 110 QFAN=13.74142	* PFAN+ 1. 05E-3	*PFAN**2-2.65-6	•PFAN
-52	X++3 \$GD TO 110		7777	
_94.		*FAN+5.925-4	*PFAN**2-1.55-6	*PFAN
	X++3 \$GO TO 110			
95	GFAN=12.57 104	*PFAN+6.93E-4	-PFAN++2-1.63E-6	*PFAN
	x••3 360 TO 110	43544. 7. 345. /	405444447-0 737-7	40541
26	OFAN=11.59062 X**3 \$G) TO 110	*3FAN+3.78E-4	*PFAN**2-9.23E-7	•PFAN
97	OFAN=12.6079	**FAN+4.79E-4	*PFAN**2-1.095-6	*PFAN
	X++3 3G0 TO 110			
9.6	OFAN=18.29205	*PFAN+1.29E-3	*PFAN**2-2.61E-6	PFAN
	x++3 \$GO TO 110			
99	OFAN=19.03213	*3FAN+1.23E-3	* OF AN * * 2 - 2 - 53E - 8	PFAN
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101.	OFAM=32.07492	*** **********************************	*PFAH ** 2-3.63E-6	FIAN
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110	QFAN=OFAN/(RHO+32.2)			
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-c-	GALL HYBARA HINIMUM GALL ISHAP IF (IS) GALL IK-PH21 GALL (GALL (GALL (GALL (AHOFH) CALL (II-R21	10 (HYII 14 UN 14 (II 15 E SE (SE (SE (SE (SE (SE (SE (SE (SE (SE	X,P K Y S T S T T T T T T T	ETGH .75) .75) .0) 1,45 0,10 1,41 1,41 1,41	T I 2TK GO -M. XSE N.P	S PA .R2 .R2 TO 1 .D	941 TK, 39 SE, ISG SE,	NS ZOX SE) YOS SL4:	BLA TK, SS, 1XS QO, SI, SE,	TTEF FH11 YCXS G,S1 YG F	R HE	EIGH LI I DELS PHE	IT K.L THE	2 1	E, Z	015°	, <u>IC</u>	LFH IS1	,R2 T	
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	GALL HYPHY MINIMUM HYPHY GALL ISHAP IF (IS) GALL (**C(HYII **HYII **X(ISE ************************************	X,P K + Y + K + 	EXCH : 1 () () () () () () () () () (T I STK GO SE S	S PA .R2 .R2 TO 1 ,DX N.D. ,ZCX MEJT .A2 .R2 M.V*	9KI TK. 39 SE. ISG SE. HE, SI. TK.	NG R1 R2 R2 R2 R2 R3 R3 R4 R3 R4 R4 R4 R4 R4 R4 R4 R4 R4 R4 R4 R4 R4	BLA TK, SS, 1XC QO, SI, SE, 1S1 TK,	YCX5	TK. HE	DELS PHE	THE	2 T CIS ,CC	E,Z ,FF 1.L H17	015 ,66 115 K,1	1, L2	IS1	,R1IS TK,L	
	GALL HINIMH HY=AM GALL ISHAP IF (IS) GALL	40(HYII FRUNCISE SECTION	X+P K + T S + D S + D T + C T + C T + C S + D T + C 	2 2 3 4 5 5 6 6 6 6 6 6 6 6 6 6 6 6 6 6 6 6 6	T I STK GO STK XSE P. S1 K	S PA .R2 TO 1 ,DX N.D., ,ZCX ME.JT .A2 .R2 M.V*	941 TK. 39 51. ISG 51. TK. TK.	NG 21 22 22 23 24 25 25 25 25 25 25 25 25 25 25 25 25 25	SS, 145 CO, 251, 151 TK, 151	Y T E F F H 1 1 Y C X S G , S 1 Y G F C I S E E S , L S 1 F Z 1	R HE TK.1 [E.F [E.F [FK.6	PHE:	THE	CIS ,CC ,CC	E, Z , F F 1. L H1 T E, A 1, X	CIS:	1, L2 L, L2 L, A2 E, ZC	IS1	,R1IS TK.L	
	GALL HINIMUM HINIMUM GALL ISHAPE IF (IS) GALL I + R Z IS	**************************************	X,P K Y Y X X X X X X X X	RAT) 1734 1734 1745	T I I STK GO SEC	S PA • R2 • TO 1 • DX • N • D • . • Z CX • M • V • . • A C · · · · · · · · · · · · · · · · · ·	941 TK. 39 SE. 156 SE. HE, TK. 151 32. CL. S1.	NG 21 20X 521 726 514 726 514 726 74 74 726	SS., 145 CO, 151 TK., 151	PH11 PH11 PKX PKX PKX PKX PKX PKX PKX P	TK. (2130 2130 2130 2130 2130 2130 2230	THE	2 T CIS ,CC,	E,Z ,FF 1.L 11T E.A 1.X	CIS: .GG: 115: K.I'	L, L2 L, L2 L, A2 E, ZC	IS1 ,L1 SI ISE HYI	,R2 T ,R1IS TK,L .OX S ,L2 T ,LX,S	
	GALL	+C(HIAUN(HIAU)(HIAUN(HIAUN(HIAUN(HIAUN(HIAUN(HIAU)(HIAUN(HIAUN(HIAU)(HIAUN(HIAUN(HIAU)(HIAUN(HIAU)(HIAUN(HIAU)(HIAUN(HIAU)(HIAU)(HIAUN(HIAU)(HIA	1	RATION () 1	T I I STK GO SECONDER	S PA •R2 •R2 •R2 •R2 •R2 •R2 •R2 •R	99 55. 156 55. HE, 51. 751 751 751 751	70 X X X X X X X X X X X X X X X X X X X	8LA TK, SS, 140 QO, 151 TK, 151 TK, 151	PHILIPPE STATE OF THE STATE OF	R HE TK.11 TK.11 TK.12 TK.12 TK.12 TK.12 TK.12 TK.12 TK.12 TK.12 TK.12 TK.12 TK.12 TK.12 TK.13 TK.14 T	PHE:	11.93 11.93 11.93 11.93 11.93 11.93	2 T CIS ,CC, EIS, .LS	E,Z ,FF 1.L H17 E.A 1.X ,AH ISG	CIS* .GG	L.L2 CLFM L.A2 E.ZC	IS1 ,L1 SI ISE HYI	,R2 T ,R1IS TK,L .OX S ,L2 T ,LX,S	
	GALL HINIMUM HINIMUM GALL ISHAPE IF (IS) GALL I + R GALL I + S Z + K Z	+C(HIAUN(HIAU)(HIAUN(HIAUN(HIAUN(HIAUN(HIAUN(HIAU)(HIAUN(HIAUN(HIAU)(HIAUN(HIAUN(HIAU)(HIAUN(HIAU)(HIAUN(HIAU)(HIAUN(HIAU)(HIAU)(HIAUN(HIAU)(HIA	1	RATION () 1	T I I STK GO SECONDER	S PA •R2 •R2 •R2 •R2 •R2 •R2 •R2 •R	99 55. 156 55. HE, 51. 751 751 751 751	70 X X X X X X X X X X X X X X X X X X X	8LA TK, SS, 140 QO, 151 TK, 151 TK, 151	PHILIPPE STATE OF THE STATE OF	R HE TK.11 TK.11 TK.12 TK.12 TK.12 TK.12 TK.12 TK.12 TK.12 TK.12 TK.12 TK.12 TK.12 TK.12 TK.13 TK.14 T	PHE:	11.93 11.93 11.93 11.93 11.93 11.93	2 T CIS ,CC, EIS, .LS	E,Z ,FF 1.L H17 E.A 1.X ,AH ISG	CIS* .GG	L.L2 CLFM L.A2 E.ZC	IS1 ,L1 SI ISE HYI	,R2 T ,R1IS TK,L .OX S ,L2 T ,LX,S	
	GALL	+C(+T) +C(+T)	X,P KY,T S+TK .E3 E4 E4TK .E3 E4TK .E3 E4TK .E3 E4TK .E3 E4TK .E3 E4TK .E3 E4TK .E3	RATION TO SHARE THE STATE OF TH	T II I STK GO = STK + ST	S PA +R2 +R2 +R2 +R2 +R2 +R2 +R2 +R2 +R2 +R2	99 55. 156 55. HE, 51. 751 751 751 751	70 X X X X X X X X X X X X X X X X X X X	8LA TK, SS, 140 QO, 151 TK, 151 TK, 151	PHILIPPE STATE OF THE STATE OF	R HE TK.11 TK.11 TK.12 TK.12 TK.12 TK.12 TK.12 TK.12 TK.12 TK.12 TK.12 TK.12 TK.12 TK.12 TK.13 TK.14 T	PHE:	11.93 11.93 11.93 11.93 11.93 11.93	2 T CIS ,CC, EIS, .LS	E,Z ,FF 1.L H17 E.A 1.X ,AH ISG	CIS* .GG	L.L2 CLFM L.A2 E.ZC	IS1 ,L1 SI ISE HYI	,R2 T ,R1IS TK,L .OX S ,L2 T ,LX,S	
	GALL HINIMH GALL ISHAPE IF (IS) GALL (GALL	+C(HYIN (1) 1	X,P HY: S+T HTK: -173 1215 1215 1215 1215 1215 1215 1215 121	RATION (1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1	T II I ZTK GO _ STK S C S C S C S C S C S C S C S C S C S	S PA +R2 TO 1 +DX +N+D+ -J ZGX -R2 -R2 -R2 -R2 -R2 -R2 -R2 -R2	7K. 39 15G 55: HE, 51. 7K: 152. CL. 152. 142.	NG 21 20 X 2 X 2 X 2 X 2 X 2 X 2 X 2 X 2 X 2	BLA TK. SS. 1XS QO. SI. 1S1 TK. SS. 1AC 1XS	PHILIPPE TO SECULATE THE SECULATION OF SECURATION OF SECURATION OF SECULATION OF SECURATION OF SECUR	R HE TK.1 TK.1 TK.1 TK.1 TK.1 TK.1 TK.1 TK.1	CSS.	1.99 1.93 1.93 1.93 1.93 1.93 1.93 1.93	2 T CLS ,CC,,, SIS,, E SS,, E SS,, E SS,, SS2,	1.L H17 E.A 1.X AH ISG	CIS* .GG	L.L2 CLFM L.A2 E.ZC	IS1 ,L1 SI ISE HYI	,R2 T ,R1IS TK,L .OX S ,L2 T ,LX,S	
	GALL	HONDING TO STAND TO S	X.P. Y.	RATION TO THE PROPERTY OF THE	T I I I STK GO SE STK SE STK SE STK SE STK SE STK SE STK SE	S PA +R2 +R2 TO 1 +DX N+D+ -JZGX -R2 -R2 -R2 -R2 -R2 -R2 -R2 -R2 -R2 -R2	7K. 39 155 155 155 155 155 155 155 155 155 15	NG 21 20XX 551 796 814 796 814 796 814 796 814 796 814 796 814 796 815 814 796 815 814 796 815 814 796 815 814 796 815 814 796 815 814 796 815 814 796 815 814 796 815 814 796 815 814 796 815 815 815 815 815 815 815 815 815 815	BLA TK. SS: 1XS QO: 1S1: 1TK. SS: 1XS 1XS 1XS 1XS 1XS 1XS 1XS 1XS 1XS 1XS	PHILIPPE TO SECULATE THE SECULATION OF SECURATION OF SECURATION OF SECULATION OF SECURATION OF SECUR	R HE TK.1 TK.1 TK.1 TK.1 TK.1 TK.1 TK.1 TK.1	CSS.	1.99 1.93 1.93 1.93 1.93 1.93 1.93 1.93	2 T CLS ,CC,,, SIS,, E SS,, E SS,, E SS,, SS2,	1.L H17 E.A 1.X AH ISG	CIS* .GG	L.L2 CLFM L.A2 E.ZC	IS1 ,L1 SI ISE HYI	,R2 T ,R1IS TK,L .OX S ,L2 T ,LX,S	
	GALL		X.P. Y.	RATION TO THE PROPERTY OF THE	T I I I STK GO SE STK SE STK SE STK SE STK SE STK SE STK SE	S PA +R2 TO 1 +DX +N+D+ -J ZGX -R2 -R2 -R2 -R2 -R2 -R2 -R2 -R2	7K. 39 155 155 155 155 155 155 155 155 155 15	NG 21 20XX 551 796 814 796 814 796 814 796 814 796 814 796 814 796 815 814 796 815 814 796 815 814 796 815 814 796 815 814 796 815 814 796 815 814 796 815 814 796 815 814 796 815 814 796 815 815 815 815 815 815 815 815 815 815	BLA TK. SS: 1XS QO: 1S1: 1TK. SS: 1XS 1XS 1XS 1XS 1XS 1XS 1XS 1XS 1XS 1XS	PHILIPPE TO SECULATE THE SECULATION OF SECURATION OF SECURATION OF SECULATION OF SECURATION OF SECUR	R HE TK.1 TK.1 TK.1 TK.1 TK.1 TK.1 TK.1 TK.1	CSS:	1.99 1.93 1.93 1.93 1.93 1.93 1.93 1.93	2 T CLS ,CC,,, SIS,, E SS,, E SS,, E SS,, SS2,	1.L H17 E.A 1.X AH ISG	CIS* .GG	L.L2 CLFM L.A2 E.ZC	IS1 ,L1 SI ISE HYI	,R2 T ,R1IS TK,L .OX S ,L2 T ,LX,S	
c.	CALL		X - P Y	RATION TO THE PROPERTY OF THE	T I I I STK GO SE STK SE STK SE STK SE STK SE STK SE STK SE	S PA +R2 +R2 TO 1 +DX N+D+ -JZGX -R2 -R2 -R2 -R2 -R2 -R2 -R2 -R2 -R2 -R2	7K. 39 155 155 155 155 155 155 155 155 155 15	NG 21 20XX 551 796 814 796 814 796 814 796 814 796 814 796 814 796 815 814 796 815 814 796 815 814 796 815 814 796 815 814 796 815 814 796 815 814 796 815 814 796 815 814 796 815 814 796 815 815 815 815 815 815 815 815 815 815	BLA TK. SS: 1XS QO: 1S1: 1TK. SS: 1XS 1XS 1XS 1XS 1XS 1XS 1XS 1XS 1XS 1XS	PHILIPPE TO SECULATE THE SECULATION OF SECURATION OF SECURATION OF SECULATION OF SECURATION OF SECUR	R HE TK.1 TK.1 TK.1 TK.1 TK.1 TK.1 TK.1 TK.1	CSS:	1.99 1.93 1.93 1.93 1.93 1.93 1.93 1.93	2 T CLS ,CC,,, SIS,, E SS,, E SS,, E SS,, SS2,	1.L H17 E.A 1.X AH ISG	CIS* .GG	L.L2 CLFM L.A2 E.ZC	IS1 ,L1 SI ISE HYI	,R2 T ,R1IS TK,L .OX S ,L2 T ,LX,S	
	GALL		X,P K + 7: H + 7: H + 7: 1 + 15: 1	RATION TO THE PROPERTY OF THE	T I I I STK GO SE STK SE STK SE STK SE STK SE STK SE STK SE	S PA +R2 +R2 TO 1 +DX N+D+ -JZGX -R2 -R2 -R2 -R2 -R2 -R2 -R2 -R2 -R2 -R2	7K. 39 155 155 155 155 155 155 155 155 155 15	NG 21 20XX 551 796 814 796 814 796 814 796 814 796 814 796 814 796 815 814 796 815 814 796 815 814 796 815 814 796 815 814 796 815 814 796 815 814 796 815 814 796 815 814 796 815 814 796 815 815 815 815 815 815 815 815 815 815	BLA TK. SS: 1XS QO: 1S1: 1TK. SS: 1XS 1XS 1XS 1XS 1XS 1XS 1XS 1XS 1XS 1XS	PHILIPPE TO SECULATE THE SECULATION OF SECURATION OF SECURATION OF SECULATION OF SECURATION OF SECUR	R HE TK.1 TK.1 TK.1 TK.1 TK.1 TK.1 TK.1 TK.1	CSS:	1.99 1.93 1.93 1.93 1.93 1.93 1.93 1.93	2 T CLS ,CC,,, SIS,, E SS,, E SS,, E SS,, SS2,	1.L H17 E.A 1.X AH ISG	CIS* .GG	L.L2 CLFM L.A2 E.ZC	IS1 ,L1 SI ISE HYI	,R2 T ,R1IS TK,L .OX S ,L2 T ,LX,S	
c.	CALL		X.P.	RATION TO THE PROPERTY OF THE	T I I I STK GO SE STK SE STK SE STK SE STK SE STK SE STK SE	S PA +R2 +R2 TO 1 +DX N+D+ -JZGX -R2 -R2 -R2 -R2 -R2 -R2 -R2 -R2 -R2 -R2	7K. 39 155 155 155 155 155 155 155 155 155 15	NG 21 20XX 551 796 814 796 814 796 814 796 814 796 814 796 814 796 815 814 796 815 814 796 815 814 796 815 814 796 815 814 796 815 814 796 815 814 796 815 814 796 815 814 796 815 814 796 815 815 815 815 815 815 815 815 815 815	BLA TK. SS: 1XS QO: 1S1: 1TK. SS: 1XS 1XS 1XS 1XS 1XS 1XS 1XS 1XS 1XS 1XS	PHILIPPE TO SECULATE THE SECULATION OF SECURATION OF SECURATION OF SECULATION OF SECURATION OF SECUR	R HE TK.1 TK.1 TK.1 TK.1 TK.1 TK.1 TK.1 TK.1	CSS:	1.99 1.93 1.93 1.93 1.93 1.93 1.93 1.93	2 T CLS ,CC,,, SIS,, E SS,, E SS,, E SS,, SS2,	1.L H17 E.A 1.X AH ISG	CIS* .GG	L.L2 CLFM L.A2 E.ZC	IS1 ,L1 SI ISE HYI	,R2 T ,R1IS TK,L .OX S ,L2 T ,LX,S	
c.	GALL		X.P.	RATION TO THE PROPERTY OF THE	T I I I STK GO SE STK SE STK SE STK SE STK SE STK SE STK SE	S PA +R2 +R2 TO 1 +DX N+D+ -JZGX -R2 -R2 -R2 -R2 -R2 -R2 -R2 -R2 -R2 -R2	7K. 39 155 155 155 155 155 155 155 155 155 15	NG 21 20XX 551 796 814 796 814 796 814 796 814 796 814 796 814 796 815 814 796 815 814 796 815 814 796 815 814 796 815 814 796 815 814 796 815 814 796 815 814 796 815 814 796 815 814 796 815 815 815 815 815 815 815 815 815 815	BLA TK. SS: 1XS QO: 1S1: 1TK. SS: 1XS 1XS 1XS 1XS 1XS 1XS 1XS 1XS 1XS 1XS	PHILIPPE TO SECULATE THE SECULATION OF SECURATION OF SECURATION OF SECULATION OF SECURATION OF SECUR	R HE TK.1 TK.1 TK.1 TK.1 TK.1 TK.1 TK.1 TK.1	CSS:	1.99 1.93 1.93 1.93 1.93 1.93 1.93 1.93	2 T CLS ,CC,,, SIS,, E SS,, E SS,, E SS,, SS2,	1.L H17 E.A 1.X AH ISG	CIS* .GG	L.L2 CLFM L.A2 E.ZC	IS1 ,L1 SI ISE HYI	,R2 T ,R1IS TK,L .OX S ,L2 T ,LX,S	
c.	CALL		X.P. X.	RATION OF THE STATE OF THE STAT	T I I I STK GO SE STK SE STK SE STK SE STK SE STK SE STK SE	S PA +R2 +R2 TO 1 +DX N+D+ -JZGX -R2 -R2 -R2 -R2 -R2 -R2 -R2 -R2 -R2 -R2	7K. 39 155 155 155 155 155 155 155 155 155 15	NG 21 20XX 551 796 814 796 814 796 814 796 814 796 814 796 814 796 815 814 796 815 814 796 815 814 796 815 814 796 815 814 796 815 814 796 815 814 796 815 814 796 815 814 796 815 814 796 815 815 815 815 815 815 815 815 815 815	BLA TK. SS: 1XS QO: 1S1: 1TK. SS: 1XS 1XS 1XS 1XS 1XS 1XS 1XS 1XS 1XS 1XS	PHILIPPE TO SECULATE THE SECULATION OF SECURATION OF SECURATION OF SECULATION OF SECURATION OF SECUR	R HE TK.1 TK.1 TK.1 TK.1 TK.1 TK.1 TK.1 TK.1	CSS:	1.99 1.93 1.93 1.93 1.93 1.93 1.93 1.93	2 T CLS ,CC,,, SIS,, E SS,, E SS,, E SS,, SS2,	1.L H17 E.A 1.X AH ISG	CIS* .GG	L.L2 CLFM L.A2 E.ZC	IS1 ,L1 SI ISE HYI	,R2 T ,R1IS TK,L .OX S ,L2 T ,LX,S	
c.	CALL		X.P.	R T T T T T T T T T T T T T T T T T T T	T I S G S S + S S + S S + S S + S S S + S	S PA R2 TO 1 100 100 100 100 100 100 100 1	7K. 39 155 155 155 155 155 155 155 155 155 15	NG 21 20XX 551 796 814 796 814 796 814 796 814 796 814 796 814 796 815 814 796 815 814 796 815 814 796 815 814 796 815 814 796 815 814 796 815 814 796 815 814 796 815 814 796 815 814 796 815 815 815 815 815 815 815 815 815 815	BLA TK. SS: 1XS QO: 1S1: 1TK. SS: 1XS 1XS 1XS 1XS 1XS 1XS 1XS 1XS 1XS 1XS	PHILIPPE TO SECULATE THE SECULATION OF SECURATION OF SECURATION OF SECULATION OF SECURATION OF SECUR	R HE TK.1 TK.1 TK.1 TK.1 TK.1 TK.1 TK.1 TK.1	CSS:	1.99 1.93 1.93 1.93 1.93 1.93 1.93 1.93	2 T CLS ,CC,,, SIS,, E SS,, E SS,, E SS,, SS2,	1.L H17 E.A 1.X AH ISG	CIS* .GG	L.L2 CLFM L.A2 E.ZC	IS1 ,L1 SI ISE HYI	,R2 T ,R1IS TK,L .OX S ,L2 T ,LX,S	
c.	CALL		X + P + T + T + T + T + T + T + T + T + T	R T T T T T T T T T T T T T T T T T T T	T I S G S S + S S + S S + S S + S S S + S	S PA R2 TO 1 100 100 100 100 100 100 100 1	7K. 39 155 155 155 155 155 155 155 155 155 15	NG 21 20XX 551 796 814 796 814 796 814 796 814 796 814 796 814 796 815 814 796 815 814 796 815 814 796 815 814 796 815 814 796 815 814 796 815 814 796 815 814 796 815 814 796 815 814 796 815 815 815 815 815 815 815 815 815 815	BLA TK. SS: 1XS QO: 1S1: 1TK. SS: 1XS 1XS 1XS 1XS 1XS 1XS 1XS 1XS 1XS 1XS	PHILIPPE TO SECULATE THE SECULATION OF SECURATION OF SECURATION OF SECULATION OF SECURATION OF SECUR	R HE TK.1 TK.1 TK.1 TK.1 TK.1 TK.1 TK.1 TK.1	CSS:	1.99 1.93 1.93 1.93 1.93 1.93 1.93 1.93	2 T CLS ,CC,,, SIS,, E SS,, E SS,, E SS,, SS2,	1.L H17 E.A 1.X AH ISG	CIS* .GG	L.L2 CLFM L.A2 E.ZC	IS1 ,L1 SI ISE HYI	,R2 T ,R1IS TK,L .OX S ,L2 T ,LX,S	

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CALL STIFY STITZ STITX STITZ STITZ YC. TZ YC
                1YCG. DVF. PCH. VCH32, SKT. PH2. PHENOT, TH2. THENOT. CKK. PAT. GG. HY 1. GEC. MSS 2. RPM. U. ST'. RHO. AGPS. AGHS. ATAS2. ATCS2. ACC. ACC.
                 32.AACS2.ACSS2.C4F,CFX.CGP.
                                                                                                                         ACFSE.ATISC, ATRSE, PERSE, XCHSE, ZCHSE,
                3XTKS2.ZTKS2.ACIS1.YGHCL.QPTFM.QTCFM.GTAFM.QCHAT)
               __CO 20_1=1,4
                    ¥1(I)=0Y ST(I)
                    Y(I):SY(I) +H*DY ST(I)
                   TIBLE STIFY STITZ 
                LYCG. DVP. PCH. VCHSZ. SKT. PHE. PHEDOT. THE . THEOOT, CKK. PAT. GG. HYI. GEC. HSS
                 2, RPM. U. SIE, PHO. AGPSZ, ACHSZ. ATASZ, ATCSZ, ACHS
32, A4CSZ, ACCSZ, CAF, CFX, CSP. AGFSZ, ATRSZ, PERSZ, KCMSZ, ZCHSZ,
                SXTKS2.21KS2.ACIS1, YGHCL, QPTFH.QTCFH. QTAFH, QGHAT)
                   CO 30 I=1.4
Y2(I)=0Y ST(1)
                   Y(I) = SY(I) + OTIME + DY ST(I)
                    Y(1)=PPL 3Y(2)=PCH 5Y(3)=PTK
CALL ST(FY ST,TY ST,TY ST,TPP,PPL,VPL,VTKS2,QFX,QVK,PTK,QVG,
                 14CG.CVP.PCH.VCH32.5KT.PHE, PHEDOT, THE THEOOT, CKK, PAT. GG, HY I. GEC, HSS
                                                                                                                           SIE . RHO. AGPSZ. ACHSZ. ATASZ. ATCSZ. ACHS
                 32.AAGS2.AC3S2.CAF.SFY.CSP.
                                                                                                                           ADFSE, ATISE, ATRSE, PERSE, XCHSE, ZCHSZ,
                 3XTKSZ.ZTKS?, ACISI.YGHCL, QPTFM, QTCFM, QTAFM. QCHAT)
                    TIME<u>STIME+H</u>
                    H=H/3.
                    00 40 1:1.4
                    PFT1=2.0 (Y1(T) - Y2(1))
                    PRT2=Y0(1)+0Y ST(1)
                    Y(I)=SY(I)+H*PRT2
               T(1)=5Y(1)+H*PRT1+H*PRT2

CONTINUE

FPL=Y(1) 3PCH=Y(2) $FTX=Y(3)

CALL ST(FY ST.TZ ST.TX ST.)Y ST.IPP.PPL.VPL.VTKS2.OFX.DVK.PTK.OVC.

1YCG.DVF.PCH.VCHS2.SK*.PHE.PHECOT.THE.THEOOT.CKK.PAT.GG.HYI.GEC.HSS
2, RPH, U, SIT.PHO.AGPS2.ACHS2.ATGS2.ATGS2.ACHS
32,ACCS2.ACCS2.CAF.GFY.CSP, AGES2.ATIS2.AFGS2.XCHS2.ZCHS2.
                 BATKS 2. 2TKS 2. ACTS 1. YGHCL , OPTEM. OTCFY, CTAFH. OCHAT)
                    IF ( (FPL-SY (1) ) . LT. 1. ) GO TO 60
                    IFITIME . LT . TINC) SO TO SO
                   CONTINUE
                   INUM#1
            *****CALCULATE CYCH, JYCHP, JYTK AS CVC, DVP, DVK
              IF(INUM)201.11,201
VCHS=VCHS2 3VTKS=VTKS2
201 CALL TRISHTK, FHOTK, RO TK, RI TK, FHITK, LI TK, LO TK, HY, A, E, L, LS) ISHAPE = ISHTK
                    CALL SELITYSE. DE SE.DX SE.ZCXSE.XCYSE.DELSE.XCISE.ZCISE.ICLFM.RZ T
                1K.PH?TK.DZTS1.LS.M.N.D.TSGSE)
                   CALL CC(SL+CO, XXXSE, ZCXSE, YZG, XZG, SZE, PHE, THE, CC+FF, GG)
CALL PR(YG PR)
                    CALL CLIVEHOL, ION PHE THE SLACO, YE PRI
                    RHOFMERHO
                CALL SICOZISI, AL SI.AZ SI.SI SI.DI SI.DXISI.BZISI, LIISI.ZISI, RIIS
11.RZISI.SNISI, PHZTK.PZ TK.OX SE.DE SE, HY.RI TK, PHITK, ICLEH, LI TK.L
XZ TK.ITYSE, D.A.Z.N.H.VTISI. ACISI.LS)
                   CALL SELVICSZ, VOHSZ, ACHSZ, AHZIK, FZ TK, OZISI, BE SE, AI SI, AZ SI, OX S
L, SI SI, IIYSE, YGHSL, HY , UI SI, OXISI, DEISI, XCISE, ZCISE, LZ T
                16.SI 51.
                ZK.L1ISI.LZISI.RIISI.RZISI.DZL35.CNISI.XCXSE.D.LS.AM.NX.NM.MYILLX.S
3M.VGO.RI TK.AG952.A1AC2.A1G5Z.ADNSZ.AAG5Z.ACG5Z.ISGSE.VTISI.ACISI,
                XACPSZ.ATISZ.ATRSZ.PEPSZ.XCHSZ.XTKSZ.7CHSZ.ZTKSZ.L.L1_TK1_
                   DVC=(VCHS 2-VCHS)/.01
                            VCHSS=VCHS? 3PRAT = (PCH+ (PTK-PCH) * . 1) /PTK
                    CALL HOCHY.PRATE
          GALL TK(ISHTK,PH2TK,R7 TK,R1 TK,FH1TK,L1 TK,L2 TK,HY,A,E,L,LS)
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ISHAPE=ISH*K	
IF(ISHAPE.EO.O) GC) TO 199
CALL SELETIVES, BE S	SE.DX ST.70XGE, XCXSE, DEUSE, XCISE, ZCISE, ICLFM, RZ T
1K.PHZTK.DZ[S1.LS.F	
	SE,7CXSE,YJG,XCG,SIE,PHE,THE,CC,FF,GG)
CALL PRIVE PRI	
CALL CLIYGHEL. ICH.	PHEITHE ISLACOING PRI
- RHOFFERHO	
	11.42 \$1.51 \$1.01 \$1.0x1\$1.8EI\$1.L1I\$1.L2I\$1.R1I\$
11,921S1.SN[S1.PH2]	K.AZ TK.OX SELAZ SELHYLRI TK.PHITK.ICLAM.LI TK.L
XZ TK, ITYSE, D, A, E, P	., M. VTIS1, ACIS1, LS)
CALL SPIVIKS2. VCHS	CAACHSCAPHETKIFE TKIDEISTIBE SEAT SLAF STADE S
16.SI S1. ITYS	1 51.32135.32138.32131.9:151.x0152.2015E.L2 T
	IL. PZISI . DILSE . ENISI, YOXSE . D.LS.AH.NX. NH. HYI, LX.S
3H,VCD,R1 TK,AGP52,	ATAS2.ATG32.ACNS2.AACS2.ACCS2.ISGSE.VTIS1.ACIS1.
WACRSZ.ATISZ.ATRSZ.	PERSZ, XCHSZ, XTKSZ, ZCHSZ, ZTKSZ, L, L1 TK)
DVP=(VCHSS-VCHS?)	
	41(1,0,(PCH/PTK1))
C CALCULATE DVTK	
CALL HC(HX,PRAT)	
HY*HX*HYI	
	Kirz TKiri TK, PHITKILI TKILZ TK, HY ALE, LILS)
	A five Title and the control of the
ISHAPE=ISHIK	
IF (ISHAPE. ED. 0) GO	10 199
CALL SECTIVES: 3E S	E.OY SE.ZCXSE, XCXSE, DELSE, XCISE, ZCISE, ICLFM, RZ T
1K,FH2TK, 02IS1,L3,H	(.N.P.ICGSE)
CALL COIST CO. YOYS	E.ZCXSE.YOG.XGG.SIE.PHE.THE.CC.FF.GGI
0414 03456 001	212343113013043161. WETT 112100411 4001
CALL PRITE PRI	the state of the s
	PHE, THE, SLACO, YO PR)
RHOFFERHO	
CALL S11021S1+A1 S	51.A2 S1.31 S1.01 S1.0xIS1.8:IS1.L1IS1.L2IS1.R1IS
11.82151.58151.8427	K,RZ TK.OK SE.BE SE,HY,P1 TK,PH1TK,ICLFM,L1 TK.L
AZ TK.ITYSE, D. 4. E. N	
CALL SELVIZED VON	2,40H52,PH2TK,F2 TK.02IS1.BE SE.A1 \$1.42 S1.0X S
12.51 S1, ITYS	The Mark the Control of the Mark the Control of the
	E.YGHOL,HY,CI S1.DXIS1.QLIS1.XCISE.ZCISE.LZ T
\$K,L1IS1,L2IS1.R1IS	1, P?ISI, D?LSE+SNIS1, XCXSE+D+LS+AH+NX+NH+H <u>YI+LX+S</u>
ZK, L1151, L2151, R115	1,P?IS1,2FLSE,ENIS1,XCXSE,D,LS,4H,HX,NH,H <u>YI,LX,S</u> ATAS2,ATC52,4CHS2,44CS2,ACCS2,ISGSE,VTIS1,4CIS1,
ZK, L1151, L2151, R115	1,P?IS1,2FLSE,ENIS1,XCXSE,D,LS,4H,HX,NH,H <u>YI,LX,S</u> ATAS2,ATC52,4CHS2,44CS2,ACCS2,ISGSE,VTIS1,4CIS1,
ZK, L1IS1, L2IS1, R1IS 3H, VCD, R1 T<, AGPS2, XACRS2, ATIS2, LTRS2,	1,P?1S1,D?LSE.SNIS1,XCXSS.D.LS.AH.NX.NH.H <u>YI.LX.S</u> ATAS2,ATCS2,ACNS2,AACS2,ACCS2,ISGSE,VTIS1,ACIS1, PERS2,XCHS2,XTKS2,ZCHS2,ZTKS <u>2,L</u> .L1_TK)
ZK,L1IS1,L2IS1.R1IS 3H,VCO.R1 TK,AGPS2, KACRS2.ATIS2.JTRS2, OVK=(VTKS2-VTKS)/,	1,P?1S1,D?LSE.SNIS1,XCXSS.D.LS.AH.NX.NH.H <u>YI.LX.S</u> ATAS2,ATCS2,ACNS2,AACS2,ACCS2,ISGSE,VTIS1,ACIS1, PERS2,XCHS2,XTKS2,ZCHS2,ZTKS <u>2,L</u> .L1_TK)
2K,L1TS1,L2TS1,R1TS 3H,VCC.R1 T<,AGP32, KACRS2,ATTS2,JTC32, OVK=(VTKS2-VTKS)/, VTK=VTKS2	1,P?1S1,D?LSE.SNIS1,XCXSS.D.LS.AH.NX.NH.H <u>YI.LX.S</u> ATAS2,ATCS2,ACNS2,AACS2,ACCS2,ISGSE,VTIS1,ACIS1, PERS2,XCHS2,XTKS2,ZCHS2,ZTKS <u>2,L</u> .L1_TK)
2K,L1TS1,L2TS1,R1TS 3H,VCD,R1 T<,AGP32, KACRS2,ATTS2,LTTS2, OVK=(VTKS2-VTKS)/, YTK=VTKS2 199 CONTINUE	1.P?ISI,2FLSE.SNISI,XCXSE.D.LS.4H.NX.NH.HYI.LX,S ATAS2,ATCS2.ACHS2.ACS2.ACCS2.ISGSE,VTISI,ACISI, PERSZ,XCHS2,XTKS2.ZCHS2.ZTKS2,L.L1_TK)
ZK,L1IS1,L2IS1.R1IS 3H,VCD.R1 IC,AGD32 XACR32.AT1S2.4T52. DVK=(VTKS2-VTKS)/. YTK=UTKS2 199 CONTINUE C CCVVERT PADIA	1,P?ISI,DELSE,ENISI,XCXSE,D,LS,AH,NX,NH,HYI,LX,S ATAS2,ATC32,ACHS2,AACS2,ACCS2,IGGSE,VIISI,ACISI, PERSZ,XCHSZ,XTKS2,ZCHSZ,ZTKSZ,L,L1 TK) 01
ZK,L1TS1,L2TS1.R1TS 3H,VCC.R1 T4,AGP32, XACRS2,ATTS2TL7S2. DVK=(VTKS2-VTKS)/- YTK=VTKS2 THETAE*THETAERO	1,P?ISI,DELSE,ENISI,XCXSE,D,LS,AH,NX,NH,HYI,LX,S ATAS2,ATC32,ACHS2,AACS2,ACCS2,IGGSE,VIISI,ACISI, PERSZ,XCHSZ,XTKS2,ZCHSZ,ZTKSZ,L,L1 TK) 01
ZK,L1IS1,L2IS1.R1IS 3H,VCD.R1 IC,AGD32 XACR32.AT1S2.4T52. DVK=(VTKS2-VTKS)/. YTK=UTKS2 199 CONTINUE C CCVVERT PADIA	1,P?ISI,DELSE,ENISI,XCXSE,D,LS,AH,NX,NH,HYI,LX,S ATAS2,ATC32,ACHS2,AACS2,ACCS2,IGGSE,VIISI,ACISI, PERSZ,XCHSZ,XTKS2,ZCHSZ,ZTKSZ,L,L1 TK) 01
ZK,L1TS1,L2TS1.R1TS 3H,VCC.R1 T4,AGP32, XACRS2,ATTS2TL7S2. DVK=(VTKS2-VTKS)/- YTK=VTKS2 THETAE*THETAERO	1,P?ISI,DELSE.SNISI,XCXSE.D.LS.AH.NX.NH.HYI.LX,S ATAS2,ATCS2.ACHS2.ACS2.ACCS2.ISGSE,VIISI.ACISI, PERSZ,XCHS2,XTKS2.ZCHS2.ZTKS2,L.L1_TK) 01 NS_TO_DEGREES
3K,L17S1,L2TS1,R1TS 3H,VCD.R1 T4,AGP32, AGP32,ATTS7,L17S9, OVE=(VTKS2-VTKS)/, TK=VTKS2	1,P?ISI,D?LSE.SNISI,XCXSE.D.LS.4H.NX.NH.HYI.LX,S ATAS2,ATC32.ACRS2.ACC32.ACC32.ISGSE,VIISI.ACISI, PERSZ,XCHSZ,XTKS2.ZCHS2.ZTKSZ,L.LI_TK) 01 NS_TO_DEGREES
1731,12151,13151,2151,3152 342,145,2514,25230x 35274,2514,2520x 452,4514,2514,2514,2514,2514,2514,2514,2	1,P?ISI,D?LSE.SNISI,XCXSE.D.LS.4H.NX.NH.HYI.LX,S ATAS2,ATC32.ACRS2.ACC32.ACC32.ISGSE,VIISI.ACISI, PERSZ,XCHSZ,XTKS2.ZCHS2.ZTKSZ,L.LI_TK) 01 NS_TO_DEGREES
1219.1219.1219.231 252924	1,P?ISI,D?LSE.SNISI,XCXSE.D.LS.4H.NX.NH.HYI.LX,S ATAS2,ATCS2.ACG.S2.ACGS2.ACGS2.ISGSE,VIISI,ACISI, PERSZ,XCHSZ,XTKS2.ZCHS2.ZTKSZ,L.LI_TK) 01 NS_TO_DEGREES
2K,L1TS1,L2TS1,R1TS 3H,VCC.R1 T4,AG932, XACRS2,ATTS2,LTRS2, DVK=(VTKS2-VTKS)/- VTK=VTKS2 199 CONTINUE C CONVERT PADIA THETAE=THETAE/RADI PHIE=OHIC/RADIAN OTHETA=DTHITAPRADI DPHIE=CPHIC/RADIAN SIE=SYE/RADIAN RATURN JENY	1,P?ISI,DELSE.SNISI,XCXSE.D.LS.AH.NX.NH.HYI.LX,S ATASZ,ATCSZ.ACHSZ.FACSZ.ACCSZ.ISGSE,VIISI.ACISI, PERSZ,XCHSZ,XTKSZ.ZCHSZ.ZTKSZ,L.LI_TK) 01 NS_TO_DEGREES AN
2K,L1TS1,L2TS1,R1TS 3H,VCC.R1 T4,AG932, XACRS2,ATTS2,LTRS2, DVK=(VTKS2-VTKS)/- VTK=VTKS2 199 CONTINUE C CONVERT PADIA THETAE=THETAE/RADI PHIE=OHIC/RADIAN OTHETA=DTHITAPRADI DPHIE=CPHIC/RADIAN SIE=SYE/RADIAN RATURN JENY	1,P?ISI,D?LSE.SNISI,XCXSE.D.LS.4H.NX.NH.HYI.LX,S ATAS2,ATCS2.ACG.S2.ACGS2.ACGS2.ISGSE,VIISI,ACISI, PERSZ,XCHSZ,XTKS2.ZCHS2.ZTKSZ,L.LI_TK) 01 NS_TO_DEGREES
2K,L1TS1,L2TS1,R1TS 3H,VCC.R1 T4,AG932, XACRS2,ATTS2,LTRS2, DVK=(VTKS2-VTKS)/- VTK=VTKS2 199 CONTINUE C CONVERT PADIA THETAE=THETAE/RADI PHIE=OHIC/RADIAN OTHETA=DTHITAPRADI DPHIE=CPHIC/RADIAN SIE=SYE/RADIAN RATURN JENY	1.P?ISI, DELSE, ENISI, XCXSE, D.L.S. AH, NX, NH, HYILLX, S. ATAS2, ATC32, ACHS2, PACS2, ACCS2, IGGSE, VIISI, ACISI, PERSZ, XCHSZ, XTKSZ, ZCHSZ, ZTKSZ, L, LI TK) NS TO DEGREES AN AN AN AN AN AN AN
ZK,L17S1,L2TS1,R1TS JK,C2GAPT JCAGE STL,SCADAN, ZGG2DAN DVK=(XTK2-CYTKS)/, YTK=YTKS2 BIOR TO BE STAND CONVERT PADIA PATE STANDAND FAND PATE STANDAND FANDAND	1,P?ISI,DELSE,ENISI, XCXSE,D,LS.AH, NX, NH, HYILLX,S ATAS2,ATCS2.ACHS2.ACCS2.ACCS2.TGGSE, VTISI.ACTS1, PERSZ,XCHSZ,XTKS2.ZCHSZ.ZTKSZ,L,L1 TK) 01 INS TO DEGREES AN AN AN AN
CONVISION OF THE STATE	1,P?ISI,DELSE,ENISI, XCXSE,D,LS.AH, NX, NH, HYILLX,S ATAS2,ATCS2.ACHS2.ACCS2.ACCS2.TGGSE, VTISI.ACTS1, PERSZ,XCHSZ,XTKS2.ZCHSZ.ZTKSZ,L,L1 TK) 01 INS TO DEGREES AN AN AN AN
ZK,LITS1,LZIS1.RITS 3H,VCC.RI TK,AGOSZ, XACRSZ,ATIS2.LTRSZ. DVK=(VTKSZ-VTKS)/- VTK=VTKSZ 199 CONTINUE C CONVERT PADIA THETAE=THETAE/RADI PHIE=OHIC/RADIAN OTHETA=DIHITA/RADI DPHIE=OHIC/RADIAN SIE=SYE/RADIAN RETURN REN' SUSRCUTINE SE(TTYP X,DZI.LS.H.N.D.TSEG C DIVISION OF THE TRUNK PEAL LS	1,P?ISI,DELSE,SNISI,XCXSE,D,LS,AM,NX,NM,MYILLX,S ATAS2,ATCS2.ACGS2.ACGS2.ACGS2.TGGSE,VTISI,ACTS1, PERSZ,XCMSZ,XTKS2.ZCMSZ.ZTKSZ,L,L1_TK) 01 INS_TO_DEGREES AN AN - PETA,DELX,ZCX,YCX.DELTA,XCHI,ZCHI,TCALL,RZ,PHIZ INTO_SIGMENTS
ZK,L17S1,L2S1,R17S JH,VCD.R1 TC,ASGREE JCACAST TC,ASGREE XSCRSZ,ATTSC.TC,SCRSZ,VTSSZ, TSSZ,TLSSZ,TSSZ,TSSZ,TSSZ,TSSZ,TSSZ,TSSZ	1,P?ISI,DELSE,ENISI, XCXSE,D,LS.AH, NX, NH, HYILLX,S ATAS2,ATCS2.ACHS2.ACCS2.ACCS2.TGGSE, VTISI.ACTS1, PERSZ,XCHSZ,XTKS2.ZCHSZ.ZTKSZ,L,L1 TK) 01 INS TO DEGREES AN AN AN AN
ZK,L1TS1,L2TS1,R1TS 3H,VCC.R1 TK,AGP32, XACR32,ATTS2,TTS2, DVK=(VTKS2-VTKS)/, VTK=VTKS2 199 CONTINUE C CCYVERT PADIA PHIE=PHIE/RAD1 PHIE=PHIE/RAD1 DIAMACATOMICAL SIE=SYE/RAD1AN RETURN XEN', SUSRCUITNE SEITTYP X,OZI.LS.H.N.O.TSEG C DIVISION OF THE TRUNK PEAL LS DIMENSION ZGX(32), X1(32)	1,P?ISI,DELSE,ENISI, XCXSE,D,LS.AH, NX.NH.HYILLX,S ATAS2,ATCS2.ACHS2.ACCS2.ACCS2.ISGSE,VIISI.ACISI, PERSZ,XCHSZ,XTKS2.ZCHSZ.ZTKSZ,L,LI TK) 01 INS TO DEGREES AN AN IND INS TO DEGREES AN AN INS TO DEGREES AN INS TO DEGREES AN AN INS TO DEGREES AN
CONTRACTOR CON	1,P?131,D?LSE.SNIS1,XCXSS.D.LS.AH.NX.NH.HYI.LX,S ATAS2,ATC32.ACHS2.FACS2.ACCS2.IGGSC,YTIS1.ACIS1, PERS2,XCMS2,XTKS2.ZCHS2.ZTKS2,L.L1 TK) 01 INS TO DEGREES AN AN . 9274,DELX,ZGX.YCX.DELTA,XCHI.ZCHI.ICALL.RZ,PHIZ INTO SEGMENTS XCX(32).ITYP(32).DELTA(32).ISEG(32).XCHI(32).ZCH
ZK,L1TS1,L2TS1,R1TS 3H,VCC.R1 TK,AGP32, XACR32,ATTS2,TTS2, DVK=(VTKS2-VTKS)/, VTK=VTKS2 199 CONTINUE C CCYVERT PADIA PHIE=PHIE/RAD1 PHIE=PHIE/RAD1 DIAMACATOMICAL SIE=SYE/RAD1AN RETURN XEN', SUSRCUITNE SEITTYP X,OZI.LS.H.N.O.TSEG C DIVISION OF THE TRUNK PEAL LS DIMENSION ZGX(32), X1(32)	1,P?131,D?LSE.SNIS1,XCXSS.D.LS.AH.NX.NH.HYI.LX,S ATAS2,ATC32.ACHS2.FACS2.ACCS2.IGGSC,YTIS1.ACIS1, PERS2,XCMS2,XTKS2.ZCHS2.ZTKS2,L.L1 TK) 01 INS TO DEGREES AN AN . 9274,DELX,ZGX.YCX.DELTA,XCHI.ZCHI.ICALL.RZ,PHIZ INTO SEGMENTS XCX(32).ITYP(32).DELTA(32).ISEG(32).XCHI(32).ZCH
CONTRACTOR CON	1.P?ISI, DELSE, ENISI, XCXSE, D.L.S. AH, NX, NH, HYILLX, S ATAS2, ATC32, ACH52, PACS2, ACC52, IGGSE, VIISI, ACISI, PERSZ, XCHSZ, XTKS2, ZCHSZ, ZTKSZ, L, LI TK) OI NS TO DEGREES AN AN AN . NETA, DELX, ZCX, YCX, DELTA, XCHI, ZCHI, ICALL, RZ, PHIZ INTO SEGMENTS XCX(32), ITYP(32), DELTA(32), ISEG(32), XCMI(32), ZCH
ZK,L1IS1,L2IS1,R1IS 3H,VCO.R1 IC,AGP32, XACR32,AIIS2,ITS22, DVK=(VTKS2-VTKS)/- YK=VTKS2 199 CONTINUE C CCYVERT PADIA PHIE = PHIE PADIA PHIE = PHIE PADIA OTHER LOCATION CONTINUE DEPLICATION CONTINUE SIE = SYENCALIAN RETURN PENIX SUBRCUITINE SECTIVE X,D2I,LS,H,Y,D,ISEG C DIVISION OF THE TRUNK PEAL LS DIMENSION ZOX(32) X1(32) CATA PI/J, 14159265 NSTOP=3 C IF FIPST CALL, COMPUTE	1.P?ISI, DELSE, SNISI, XCXSE, D.LS.AH, NX, NH, HYILLX, SATAS2, ATGS2, AGGS2, AGGS2, AGGS2, IGGSE, VIISI, AGGS1, PERSZ, XCHSZ, XTKS2, ZCHSZ, ZTKSZ, L, LI TK) INS TO DEGREES AN AN AN CHETA, DELX, ZCX, YCX, DELTA, XCHI, ZCHI, IGALL, RZ, PHIZ INTO SIGNENTS XCX(32), ITYP(32), DELTA(32), ISEG(32), XCHI(32), ZCH 27 PARTIAL TIPMS AND NUMBER SEGMENTS
ZK,L1TS1,L2TS1,R1TS 3H,VCC.R1 T<,AGP32, XACRS2,ATTS2,LTS32, DVK=(VTKS2-VTKS)/- YTK=VTKS2 199 CONTINUE C CCVVERT PADIA PHIE=PHIE/RAD1 PHIE=PHIE/RAD1 DPHIE=CHICKPAD1A SIE=SYE/RAD1AN RETURN XEN' SUSRCUITNE SETTYP X,D21.LS.H,N,D,TS50 C DIVISION OF THE TRUNK PEAL LS DIMENSION ZCX(32)- X1(32) CATA PI/3.14159265 C IF FIPST CALL,COMPUTS IF (ICALL) 20,30,20	1.P?ISI, DELSE, SNISI, XCXSE, D.LS.AH, NX, NH, HYILLX, SATAS2, ATGS2, AGGS2, AGGS2, AGGS2, IGGSE, VIISI, AGGS1, PERSZ, XCHSZ, XTKS2, ZCHSZ, ZTKSZ, L, LI TK) INS TO DEGREES AN AN AN CHETA, DELX, ZCX, YCX, DELTA, XCHI, ZCHI, IGALL, RZ, PHIZ INTO SIGNENTS XCX(32), ITYP(32), DELTA(32), ISEG(32), XCHI(32), ZCH 27 PARTIAL TIPMS AND NUMBER SEGMENTS
ZK,L17S1,L2S1,R1SS JH,VCD.R1 CY,AGGS2 XACRS2,VCASTIS?.ZTR52, DVK=(VTKS2-VTKS)/, TOKE (VTKS2-VTKS)/, THETASAT SALIAN PHISASTANT SALIAN PHISASTANT SALIAN DORNATION TOKE SALIAN RETORN ZENT SALIAN RETORN ZEN	1.P?ISI, DELSE, ENISI, XCXSE, D.LS. AH, NX, NH, HYILLX, S ATAS2, ATC32, ACHS2, PACS2, ACCS2, IGGSE, VIISI, ACISI, PERSZ, XCHSZ, XTKS2, ZCHSZ, ZTKSZ, L, L1 TK) OI NS TO DEGREES AN AN AN . NETA, DELX, ZCX, YCX, DELTA, XCHI, ZCHI, ICALL, RZ, PHIZ INTO SEGMENTS XCY(32), ITYP(32), DELTA(32), ISEG(32), XCHI(32), ZCH 3/ PARTIAL TEPMS AND NUMBER SEGMENTS
ZK,L17S1,L2TS1,R1TS JH,VCD.R1 TC,AGP32, XACR32,AT1S2,T2S2, DVK=(VTKS2-VTKS)/, TYKE PT SATION THE TABLE THE TABLE PT SATION OTHER TO SATION OTHER TO SATION OTHER TO SATION OTHER TO SATION SIE SYSTEM SATION RETURN JEN' SUBCOULINE SECTIVE X,D21,LS,H,N,D,ISEC C DIVISION OF THE TRUNK PEAL LS DIMENSION ZCX(32), X1(32) UATA PI/J,14159265 OTHER TO SATION C OF FIRST CALL,COMPUTS IF (ICALL) 20,30,20 30 RESHER,SELS C BETA IS CURVED SCGMENT	1.P?ISI, DELSE, ENISI, XCXSE, D.LS.AH, NX, NH, HYILLX, S ATAS2, ATCS2, ACHS2, AACS2, ACCS2, IGGSE, VIISI, ACISI, PERSZ, XCHSZ, XTKS2, ZCHSZ, ZTKSZ, L, LI TK) OI NS TO DEGREES AN AN AN . META, DELX, ZCX, YCX, DELTA, XCHI, ZCHI, ICALL, RZ, PHIZ INTO SECHENTS YCX(32), ITYP(32), DELTA(32), ISEG(32), XCHI(32), ZCH 3/ 22 PARTIAL TEPMS AND NUMBER SEGMENTS
ZK,L1IS1,L2IS1,R1IS 3H,VCC.R1 IC,AGP32, XACRS2,ATIS2,LTS22, DVK=(VTKS2-VTKS)/- YKEVTKS2 199 CONTINUE C CCVVERT PADIA PHETAE-THETAEAPADI PHIE-PHIE/RADI DTHOTA-DTHITA-RADI DPHIE-SYLANDA SIE-SYLADIAN RETURN SEN' SUSRCUITNE SE(TIYP X,D2I.LS.H.Y.D.1SEG C DIVISION OF THE TRUNK PEAL LS DIMENSION ZOX(32)- X1(32) CATA PI/J.14159265 VSTOP-US C IF FIRST CALL,COMPUTS IF (ICALL) 20,30,20 RLSH-O.**LS C STA IS CURVEO SCGHENT BETA IS CURVEO SCGHENT	1.P?ISI, DELSE, SNISI, XCXSE, D.LS.AH, NX, NH, HYILLX, SATAS2, ATGS2, AGGS2, AGGS2, AGGS2, AGGS2, VISI, AGGS1, PERSZ, XCHSZ, XTKSZ, ZCHSZ, ZTKSZ, L, LL TK) OI NS TO DEGREES AN AN AN C. NETA, DELX, ZCX, YCX, DELTA, XCHI, ZCHI, ICALL, RZ, PHIZ INTO SEGMENTS XCX(32), ITYP(32), DELTA(32), ISEG(32), XCHI(32), ZCH 37 PARTIAL TEPMS AND NUMBER SEGMENTS
ZK,L17S1,L2TS1,R1TS JH,VCD.R1 TC,AGP32, XACR32,AT1S2,T2S2, DVK=(VTKS2-VTKS)/, TYKE PT SATION THE TABLE THE TABLE PT SATION OTHER TO SATION OTHER TO SATION OTHER TO SATION OTHER TO SATION SIE SYSTEM SATION RETURN JEN' SUBCOULINE SECTIVE X,D21,LS,H,N,D,ISEC C DIVISION OF THE TRUNK PEAL LS DIMENSION ZCX(32), X1(32) UATA PI/J,14159265 OTHER TO SATION C OF FIRST CALL,COMPUTS IF (ICALL) 20,30,20 30 RESHER,SELS C BETA IS CURVED SCGMENT	1.P?ISI, DELSE, SNISI, XCXSE, D.LS.AH, NX, NH, HYILLX, SATAS2, ATGS2, AGGS2, AGGS2, AGGS2, AGGS2, VISI, AGGS1, PERSZ, XCHSZ, XTKSZ, ZCHSZ, ZTKSZ, L, LL TK) OI NS TO DEGREES AN AN AN C. NETA, DELX, ZCX, YCX, DELTA, XCHI, ZCHI, ICALL, RZ, PHIZ INTO SEGMENTS XCX(32), ITYP(32), DELTA(32), ISEG(32), XCHI(32), ZCH 37 PARTIAL TEPMS AND NUMBER SEGMENTS
ZK,L1TS1,L2TS1,R1TS 3H,VCC.R1 TK,AGP32, XACRS2,ATTS2,TTS2, DVK=(VTKS2-LTS2,C) PVK=(VTKS2-VTKS)/- VTK=VTKS2 199 CONTINUE C CCVVERT PADIA PHIEAPHICACADIA PHIEAPHICACADIA DIAMACADIA DIAMACADIA DIAMACADIA SIESYEADIAN RETURN XENO SUSACUITURE SEITTYP X,D21.LS.H,N,D.TS50 C DIVISION OF THE TRUNK PEAL LS DIMENSION ZCX(32)- X1(32) CATA PI/3.1-159265 VSTO-2 C IF FIRST CALL,COMPUTS C STENS COMPUTS C STENS CONTROL BETAL SCHOOL BETAL SCHOOL BETAL SCHOOL C DELX IS STPAIGHT SEGME	1,P?ISI,DELSE, SNISI, XCXSE, D.LS.AH, NX, NH, HYILLX, S ATAS2, ATCS2, ACHS2, PACS2, ACCS2, ISCSE, VIISI, ACISI, PERSZ, XCHSZ, XTKS2, ZCHSZ, ZTKSZ, L, LI TK) OI INS TO DEGREES AN AN AN INTO SEGMENTS YCY(32), ITYP(32), DELTA, XCHI, ZCHI, ICALL, RZ, PHIZ YCY(32), ITYP(32), DELTA(32), ISEG(32), XCMI(32), ZCH ARC ANGLE ARC ANGLE INT LENGTH
C C C C C C C C C C	1.P?ISI, DELSE, ENISI, XCXSE, D.LS.AH, NX, NH, HYILLX, S ATAS2, ATCS2, ACC, S2, ACCS2, ACCS2, IGGSE, VIISI, ACISI, PERSZ, XCHSZ, XTKS2, ZCHSZ, ZTKSZ, L, LI TK) OI NS TO DEGREES AN AN AN CRETA, DELX, ZGX, YGX, DELTA, XCHI, ZCHI, IGALL, RZ, PHIZ INTO SEGMENTS YCY(32), ITYP(32), DELTA(32), ISEG(32), XCMI(32), ZGH 3/ 2 PARTIAL TERMS AND NUMBER SEGMENTS ARC ANGLE INT LENGTH
ZK,L1TS1,L2TS1,R1TS JH,VCD.R1 TC,AGP32, AGCR32,ATTS2,TS2,CGC2,TCS2,CDVKCTC,CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC	1.P?ISI, DELSE, ENISI, XCXSE, D.LS.AH, NX, NH, HYILLX, S ATAS2, ATCS2, ACC, S2, ACCS2, ACCS2, IGGSE, VIISI, ACISI, PERSZ, XCHSZ, XTKS2, ZCHSZ, ZTKSZ, L, LI TK) OI NS TO DEGREES AN AN AN CRETA, DELX, ZGX, YGX, DELTA, XCHI, ZCHI, IGALL, RZ, PHIZ INTO SEGMENTS YCY(32), ITYP(32), DELTA(32), ISEG(32), XCMI(32), ZGH 3/ 2 PARTIAL TERMS AND NUMBER SEGMENTS ARC ANGLE INT LENGTH

	· · · · · · · · · · · · · · · · · · ·
	IF(I,LE.N)[SEG(I)=1
	IF(I.GT.N.AY).I.LE.MOM)ISES(I)=2
	IF (1. GT. N - 1. AND. 1. L T. N - ? - H) [5 [6 [1] = 3
	IF(I.ST-N+294.AVD.I.LT.29(N+M))ISEG(I)=4
	IF(I.ST. 2.*(N+M). ANO. I.LI. 3.*N+2+M) ISEG(I)=5
	_ IF(I,GT,3°4'+2*4,4N^,I,LI,3*(N+4))ISEG(I)=6
	IF(1.GT.3*(NoH).AND.I.LE.3*No4*1) ISEG(1)=7
	IF(I.GT.3-Y-W-M.AND.I.LE.4-(N+M)) ISEG(I)=8
11	CONTINUE
C EVA	LUATING PROPERTIES OF SEGMENTS
C ITY	PET FOR CURVED SEGMENT. = 0 FOR STRAIGHT SEGMENT
C 4C4	AND TOX ART X AND Z COORDINATTS FESS. OF THE SESHENT CENTER T AND ZCHI ART X AND Z COORDINATES RESP. OF THE CUSHION
	AND TOWART A MAN E CONTRIBUTION OF THE SECHENI CENTER
C XCH	I AND ZCHI ARE X AND Z COORDINATES RESP. OF THE CUSHION
C PRE	SSURE CENTER FOR A SEGMENT-AMEN IT IS OUT OF GROUND CONTACT
C DEL	TA IS SEGMENT CENTER ANGLE RELATIVE TO CG
. 20	CONTINUE
	05*0.5*0+c;*SIM(PHIS)
·	00 10 I=1,4STOP
	KG0=ISEG(I)
	GO TO (1,2,3,4,5,6,7,8), KGO
C CHE	VEO SEGMENT
0 00	VEC SIGNINI
CIF	NOT INITIAL CALL SKIP CALCULATIONS
1	If(ICALL) 3,100,3
100	11YF (1) *1
	OSLTA(1) = (=LOAT(1-1)+0.5) *3:TA
	GOSDEL=COS(DELTA(I))
·	
	XCX(I)=-(RL5M+02I+COSDEL)
	ZCX(I)=02I*SIN(CELT4(I))
	(1202025AT3B*15C+H2JF) -x(1) IHDX
	2CHI(I):2CX(I):3ETA2
	GO TO 9
	GO TO 9 AIGHT SEGMENT ITYP(I)=6
C 2IN	AIGHT SEGNENT
2	ITYP(I)=G
	XCX(I)==RL5H+(FLQAT(I-1-N)+0.5)+DELX
	ZCX(1)=02
	XCHI(I)=XCX(I)
	ZCHI(I) = ZCX(I) + 0.5
	60 70 9
C STR	AIGHT SEGMENT
_3	ITYP(I)=0
	XCX (I) = (FL)4T (I-H-Y-1)+0.5) *DELX
	ZCX(1):02
	xCHI(I)=xCY(!)
	ZCHI(I)=ZCX(I)+0.F
	60 10 9
C C.1101	VLC SEGMENT
COA	/EC 350FBN
	NOT INITIAL CALL SKIP CALCULATIONS
_ 4	IF(ICALL) 3.400.9
400	DELTA(1) = (FL)AT(1-N-2-M-1)+0.5)+PETA
	SINGELESINGELTA(II)
	XCXIII: RLS 4+ 32 I * SI NOEL
	ZCX(I)=D21*D0S(DELT4(I))
	JECHI 2+SAT ER*150+HZ J4+HZ
	ZCHI(1)=ZC((1)=9EYAZ
	GO TO 9
	VER SEGMENT
C IF '	FOR INITIAL CALL SKIP CALCULATIONS
5	IF(ICALL) 3,500,9
500	17YP(1)=1
	DELTA(1) = (FLOAT(1-2*M-2*M-1)+0.5)*BETA
	COSDEL*COS(DELTA(I))
	#CX(I)=RLSH+D2I+COSOEL
	ZCX(I)=-DZ[-SIN(DTLTA(I))
	XCHI4I1:RL5H+027*COSOFL*95Ta2
	SCHI(1):SC((1)+):195
	60 10 3

	IGHT SEGMENT
. •	ITYP(I)=0
	XCX(1)=RLSH-(FLOAT(1-3*4-2*4-1)+0.5)*0ELX
•	2Cx(1):-02
	XCH1(1)*XCX(1) ZCH1(1)*ZCX(1)*0.5
-	GO TO 9
C 510.	JOHT SEGMENT
7	18YP (1/=0
•	XCX (I) =- (FLOAT (I-3*N-3*M-1)+0.5)*DJLX
	\$Cx(I)=-02
-	XCHI(1)=XCK(1)
	7CHI(1)*2CX(1)*0.5
. <u>.</u> .	60 10 9
	EC SEGMENT
,C IF N	OT INITIAL CALL SKIP CALCULATIONS
	IF(!CALL) 9,800.9
~ '€ 00. · ·	ITYP(I)=1
	DELTA(I):(FLOAT(T-3*N-4*M-1)+0.5)*8ETA SINCEL*SIN(DELTA(I))
	XCX(I)=-(P.SH+D2I*SINDEL)
	ZCX(I)=-02!*C0S(0ELTA(I))
	(SATEC-JEONIZ-1SCHES) -= (T) HOX
	ZCH1(I)=ZCK(I)+3ETA2
	CONTINUE
_ 10 _	CONTINUE
	RETURN
 -	£ ND
	SUBROUTINE TK(ISHAPE, PHIZ, RZ, RI, FHII, LI, LZ, HY, A, B, L, LS)
C TRUY	K GEOMETRY CALCULATIONS
	REAL LILLILES
	RTOL=.1 IF(HY-LE.0.)) GO TO 111
C++++	4*************************************
	ATION FOR 32
	UTE INNER RADIUS OF CURVATURE
	R2+SORT (A+4+0.2: +HY+HY)
C	
C ITER	ATION LOOP FOR 12,60,91,52
	CO 102 I=1,50
	DO 102 1-1120
	PHI2=485(A))S(AMAXI(-1.0.4MINI(1.0.((R2-HY)/R2)))))
	PHI?=485(4)35(AMAXI(-1.3,AMIN1(1.0,(K2-HY)/R2)))) SINPH2=SIN(PHI2)
	PHIZ=485(4)35(AMAXI(-1.3,AMIN1(1.0.((RZ-HY)/RZ)))) SINPHZ=SIN(PHIZ) UTE CUTER RADIUS OF CUPVATURE
	PHI2=405(4)35(444X1(-1,0,44IN1(1,0,((R2-MY)/R2)))) SINPM2=SIM(PMI2) UTE CUTER RADIUS OF CUPVATURE K1=((4-R2-51)PM2)**2+(4-MY)**2)/(2,*(8+MY))
	PHI2=405(A)35(AMAX1(-1,0,AMIN1(1,0,((R2-HY)/R2)))) SINPH2=SIM(PHI2) OTE CUTER SIADIUS OF CUPVATURE K1=((A-R2*31PH2)**2*(A*HY)**2)/(2,*(B*HY)) PHI1=405(A)305(AMAX1(-1,0,AMIN1(1,0,((R1-HY-8)/R1))))
	PHI2=485(A)S(AMAXI(-1.0,AMINI(1.0,((R2-HY)/R2)))) SINPH2=SIM(PHI2) UTE CUTER RADIUS OF CUPVATURE R1=((A-R2+3IMPH2)++2+(R+HY)+2)/(2.+(B+HY)) PHI1=AP5(A)O5(AMAXI(-1.0,AMINI(1.0,((R1-HY-8)/R1)))) XS=A-R2+SIMPH2
	PHI2=AQS(ACOS(AMAXI(-1.0.AMINI(1.0.((R2-MY)/R2)))) SINPM2=SIM(PMI2) UTE CUTER RADIUS OF CUPVATURE R1=((A-R2*SIMPM2)**2+(A*MY)**2)/(2.**(B*MY)) PHI1=APS(ACOS(AMAXI(-1.0.AMINI(1.0.((R1-MY-8)/R1)))) XS*A-R2*SIMPM2 IF (XS.LF.0.0) PHI1=6.2831952-PMI1
	PHI2=405(A)35(AMAXI(-1,0,AMINI(1,0,((R2-HY)/R2)))) SINPH2=SIM(PHI2) UTE CUTER RADIUS OF CUPVATURE K1=((A-R2*514PH2)**2+(A+HY)**2)/(2,*(B+HY)) PHI1=405(A)35(AMAXI(-1,0,AMINI(1,0,((R1-HY-8)/R1)))) X5*A-R2*SIMPH2 IF (X5*LF.3,0) PHI1=6.2831952-PHI1 L2=L-PHI1**Q1
	PHI2=405(A)35(AMAXI(-1,0,AMINI(1,0,((R2-HY)/R2)))) SINPH2=SIN(PHI2) WIE CUITER RADIUS OF CUPVATURE K1=((A-R2*519PH2)**2+(A-HY)**2)/(2,*(B+HY)) PHI1=405(A)35(AMAXI(-1,0,AMINI(1,0,((R1-HY-8)/R1))))) X\$=A-R2*SINPH2 IF (XS.LF.J.0) PHI1=6.2831952-PHI1 LZ=L-PHI1**01 IS RESULTANT RADIUS FOR COMPUTED LZLIN ITERATION
C RZS	PHI2=A85(ACOS(AMAXI(-1,0,AMINI(1,0,((R2-NY)/R2)))) SINPN2=SIY(PHI2) UTE CUTER RADIUS OF CUPVATURE Ri=((A-R2*51yPH2)**2+(A+NY)**2)/(2,*(B+NY)) PHI1=A85(ACOS(AMAXI(-1,0,AMINI(1,0,((R1-NY-8)/R1))))) X\$WA-R2*SIYPH2 IF (X\$S.L5.0.0) PHI1=6.2831952-PHI1 LZ=L-PHI1**QI IS RESULTANT RADIUS FOR CONPUTED LZLIN ITERATION IF(A95(PHI2),LT.1.05-2) PHI2=1,0E-2 PZS=LZ/PHIZ*
C RZS	PHI2=A85(ACOS(AMAXI(-1,0,AMINI(1,0,((R2-NY)/R2)))) SINPN2=SIY(PHI2) UTE CUTER RADIUS OF CUPVATURE Ri=((A-R2*51yPH2)**2+(A+NY)**2)/(2,*(B+NY)) PHI1=A85(ACOS(AMAXI(-1,0,AMINI(1,0,((R1-NY-8)/R1))))) X\$WA-R2*SIYPH2 IF (X\$S.L5.0.0) PHI1=6.2831952-PHI1 LZ=L-PHI1**QI IS RESULTANT RADIUS FOR CONPUTED LZLIN ITERATION IF(A95(PHI2),LT.1.05-2) PHI2=1,0E-2 PZS=LZ/PHIZ*
C RZS	PHI2=AQS(A)S(AMAXI(-1,0,AMINI(1,0,((R2-HY)/R2)))) SINPH2=SIN(PHI2) UTE CUTER RADIUS OF CUPVATURE K1=((A-R2*SI)PH2)**2+(A+HY)**2)/(2,*(B+HY)) PHI1=AQS(A)OS(AMAXI(-1,0,AMINI(1,0,((R1-HY-8)/R1))))) X\$=A-R2*SINPH2 IF (XS.LE.J.O) PHI1=6.2831952-PHI1 L2=L-PHI1*Q1 IS RESULTANT RADIUS FOR COMPUTED LZLIN ITERATION IF(A9S(PHI2).LT.1.0E-2) PHI2=1,0E-2 PZS=LZ/PHIZ IF TOLERANCE .GT. ERPOR IF (49S(R2-R2S).LE.PTOL) GO TO 50
C RZS	PHI2=AQS(A)S(AMAXI(-1, 0, AMINI(1, 0, ((R2-NY)/R2)))) SINPN2=SIM(PMI2) UTE CUTER RADIUS OF CUPVATURE RI=((A-R2*3IMPH2)**2+(A*HY)**2)/(2, *(B+HY)) PHI1=AQS(A)OS(AMAXI(-1, 0, AMINI(1, 0, ((R1-HY-8)/R1)))) XS*A-R2*SIMPH2 IF (XS.L5*.0.0) PHI1=6, 2831952-PHI1 L2=L-PHI1**QL L2=L-PHI1**QL IS R2SULTANT RADIUS FOR COMPUTED LZLIN ITERATION IF(AQS(PHI2)*, LT*.1.05-2) PHI2=1, 0E-2 PZS=LZ/PHI2 IF TOLERANCE .GT*. ERPOR IF (AQS(R2-R2S)*, LE*. PTOL) GO TO 50 R2=(AQS(R2-R2S)*, LE*. PTOL) GO TO 50
C RZS	PHI2=A85(ACOS(AMAXI(-1,0,AMINI(1,0,((R2-NY)/R2)))) SINPN2=SIY(PHI2) UTE CUTER RADIUS OF CUPVATURE Ri=((A-R2*319PH2)**2+(A+NY)**2)/(2,*(8+MY)) PHI1=A85(ACOS(AMAXI(-1,0,AMINI(1,0,((R1-NY-8)/R1)))) X\$WA-R2*SIYPH2 IF (XS.LE.O.O) PHI1=6.2831952-PHI1 L2=L-PHI1**Q! IS RESULTANT RADIUS FOR COMPUTED LZEIN ITERATION IF(A9S(PHI2).LT.1.0C-2) PHI2=1,0E-2 PZS=LZ/PHIZ IF TOLERANCE .GT. ERPOR IF(A9S(R2-R2S).LE.RTOL) GO TO SO R2=(A2-R2S).D_S CONTINUE
C R2S	PHI2=AQS(A)S(AMAXI(-1,0,AMINI(1,0,((R2-NY)/R2)))) SINPN2=SIN(PMI2) UTE CUTER RADIUS OF CUPVATURE K1=((A-R2*519PM2)**2+(A+MY)**2)/(2,*(B+MY)) PHI1=AQS(A)OS(AMAXI(-1,0,AMINI(1,0,((R1-MY-8)/R1))))) X\$=A-R2*SINPM2 IF (X\$.L\$.0.0) PHI1=6.2831952-PHI1 L2=L-PMI1*QL IS RESULTANT RADIUS FOR COMPUTED LZEIN ITERATION IF(AQS(PHI2),LT.1.05-2) PHI2=1,05-2 PZ\$=LZ/PHIZ IF TOLERANCE .GT. ERPOR IF(AQS(R2-R2S).LE.PIOL) GO TO 50 R2=(R2*R2S)*0.5 CONTINUE
C R2S	PHI2=AQS(A)S(AMAXI(-1,0,AMINI(1,0,((R2-HY)/R2)))) SINPH2=SIN(PHI2) UTE CUTER RADIUS OF CUPVATURE & = ((A-R2*SI)PH2)**2+(A-HY)**2)/(2,*(B+HY)) PHI1=AQS(A)OS(AMAXI(-1,0,AMINI(1,0,((R1-HY-8)/R1))))) X\$=A-R2*SINPH2 IF (XS.LE.J.O) PHI1=6.2831952-PHI1 LZ=L=PHI1**Q! IS RESULTANT RADIUS FOR COMPUTED LZEIN ITERATION IF (AQS(PHI2),LT.1.05-2) PHI2=1,0F-2 PZS=LZ/PHIZ IF 10LERANCE .GT. ERPOR IF (A4S(R2-R2S)*0.5 CONTINUE ATEO 50 TIMES MITHOUT SUCCESS.ERROR RETURN
C RZS	PHI2=AQS(A)S(AMAXI(-1, 0, AMINI(1, 0, ((R2-NY)/R2)))) SINPN2=SIN(PMI2) UTE CUTER RADIUS OF CUPVATURE Ri=((A-R2*)319H2)**2+(A+HY)**72)/(2, *(B+HY)) PHI1=AQS(A)OS(AMAXI(-1, 0, AMINI(1, 0, ((R1-HY-8)/R1)))) XS*A-R2*SINPH2 IF (XS.L5.0, 0) PHI1=6.2831952-PHI1 L2=L-PHI1**QL L2=L-PHI1**QL IS RISULTANT RADIUS FOR COMPUTED LIVEN ITERATION IF(AQS(PHI2), LT.1.05-2) PHI2=1,05-2 PZS=LZ/PHI2* IF 10LERANCE +GT. ERPOR IF (AUS(R2-R2S): LE.PIOL) GD TO 50 R2=(A2+R2S)*0_X CONTINUE ATED 50 II 12S MITHOUT SUCCESS, ERROR RETURN CONTINUE
C RZS C TEST 102 C TER 111	PHI2=A95(A)S(AMAXI(-1, 0, AMINI(1, 0, ((R2-NY)/R2)))) SINPN2=SIY(PHI2) UTE CUTER RADIUS OF CUPVATURE Ri=((A-R2*)319PH2)**2+(A+NY)**2)/(2,*(B+NY)) PHI1=A95(A)OS(AMAXI(-1, 0, AMINI(1, 0, ((R1-NY-8)/R1)))) X\$\(\frac{1}{2}\) X\$
C RZS	PHI2=AQS(A)S(AMAXI(-1, 0, AMINI(1, 0, ((R2-NY)/R2)))) SINPN2=SIY(PMI2) UTE CUTER RADIUS OF CUPVATURE Ri=((A-R2*519PM2)**2+(A+NY)**2)/(2, *(B+MY)) PHI1=AQS(A)OS(AMAXI(-1, 0, AMINI(1, 0, ((R1-NY-8)/R1))))) X\$=A-R2*SIYPN2 IF (X\$.L\$.0.0) PHI1=6.2831952-PHI1 L2=L-PMI1**QL IS RESULTANT RADIUS FOR COMPUTED LZEIN ITERATION IF(AQS(PHI2), LT.1.05-2) PHI2=1,05-2 PZ\$=LZ/PHI2 IF 10L\$ANCE .GT. ERPOR IF(AYS(R2-R2S).L\$. PTOL) GO TO \$0 R2=(R2+R2S)*0.5 CONTINUE ONLY ATED 50 II 45 WITHOUT SUCCESS, ERROR RETURN CONTINUE FORMAT(10X,* INFEASANLE TRUNK GEOMETRY *//)
C RZS C TEST 102 C.000 C 17ER 111 5011	PHI2=AQS(ACOS(AMAXI(-1, 0, AMINI(1, 0, ((R2-MY)/R2)))) SINPN2=SIM(PMI2) UTE CUTER RADIUS OF CUPVATURE Ri=((A-R2*3IMPH2)**2+(A*MY)**2)/(2, *(B+MY)) PHI1=AQS(ACOS(AMAXI(-1, 0, AMINI(1, 0, ((R1-MY-8)/R1)))) XS*A-R2*SIMPH2 IF (XS.LE.O.0) PHI1=6.2831952-PHI1 L2=L-PMI1**QL L2=L-PMI1**QL IS RESULTANT RADIUS FOR COMPUTED LZLIN ITERATION IF(AQS(PMI2), LT.1.05-2) PHI2=1,0E-2 PZS=LZ/PHI2 IF TOLERANCE .GT. ERPOR RF (AQS(R2-R2S)**LE.PTOL) GO TO 50 R2=(AQS(R2-R2S)**LE.PTOL) GO TO 50 R2=(AQS(R2-R2S)**LE.PTOL) GO TO 50 R2=(AQS(R2-R2S)**LE.PTOL) GO TO 50 R7=(AQS(R2-R2S)**LE.PTOL) GO TO 50 R7=(AQS(R
C RZS C TEST 102 C TEST 111 5011	PHI2=A95(A)S(AMAXI(-1, 2, AMINI(1, 0, ((R2-NY)/R2)))) SINPN2=SIY(PHI2) UTE CUTER RADIUS OF CUPVATURE Ri=((A-R2*)SIYPH2)**2+(A+NY)**2)/(2,*(B+NY)) PHI1=A95(A)OS(AMAXI(-1, 0, AMINI(1, 0, ((R1-NY-8)/R1)))) XS*A-R2*SINPN2 IF (XS,LE, 0, 0) PHI1=6, 2831952-PHI1 L2=L-PHI1**Q! IS RESULTANT RADIUS FOR COMPUTED LZEIN ITERATION IF(A9S(PHI2), LT.1.05-2) PHI2=1,0E-2 PZS=LZ/PHIZ IF 10LERANCE .GT. ERPOR IF(A9S(R2-R2S), LE.PIOL) GD TO 50 RZ=(R2+R2S)*0,5 CONTINUE ATED 50 II 1=S WITHOUT SUCCESS, ERROR RETURN CONTINUE MRITE(6,9011) FORMAT(10X,* INFEASANLE TRUNK GEOMETRY *//) ISHAPE=0 RETUEN
C RZS C TEST 102 C TEST 111 5011	PMIZ=AQS(A)S(AMXX(-1, 0, AMINI(1, 0, ((RZ-MY)/RZ)))) SINPNZ=SIY(PMIZ) UTE CUTER RADIUS OF CUPVATURE Ki=((A-RZ*)SIYPMZ) **2+(A*MY)**2)/(Z**(B*MY)) PMII=AQS(A)OS(AMXXI(-1, 0, AMINI(1, 0, ((RI-MY-8)/RI)))) X\$\$A-RZ*SIYPMZ IF (X\$.L\$.J.0) PMII=6.2831952-PMII LZ=L-PMII*QL IS RZSULTANT RADIUS FOR COMPUTED LZLIN ITERATION IF(A9S(PMIZ)*,LT.1.0\$-2) PMIZ=1,0\$-2 PZS=LZ/PMIZ IF TOL\$RANCE .GT. ERPOR IF(A9S(RZ-RZS)*,LE.RTOL) GO TO BO RZ*(AZ*RZS)*,LE.RTOL) GO TO BO CONTINUE ATEO BO TIMES MITHOUT SUCCESS,ERROR RETURN CONTINUE MRITE(6.9011) FOPMAT(1)X,* INFEASANLE TRUNK GEOMETRY *//) ISHAPE=0 K OK, QETURN
C RZS C TEST 102 C 102 C 111 5011 C TRUN	PHI2=A95(A)S(AMAXI(-1, 2, AMINI(1, 0, ((R2-NY)/R2)))) SINPN2=SIY(PHI2) UTE CUTER RADIUS OF CUPVATURE Ri=((A-R2*)SIYPH2)**2+(A+NY)**2)/(2,*(B+NY)) PHI1=A95(A)OS(AMAXI(-1, 0, AMINI(1, 0, ((R1-NY-8)/R1)))) XS*A-R2*SINPN2 IF (XS,LE, 0, 0) PHI1=6, 2831952-PHI1 L2=L-PHI1**Q! IS RESULTANT RADIUS FOR COMPUTED LZEIN ITERATION IF(A9S(PHI2), LT.1.05-2) PHI2=1,0E-2 PZS=LZ/PHIZ IF 10LERANCE .GT. ERPOR IF(A9S(R2-R2S), LE.PIOL) GD TO 50 RZ=(R2+R2S)*0,5 CONTINUE ATED 50 II 1=S WITHOUT SUCCESS, ERROR RETURN CONTINUE MRITE(6,9011) FORMAT(10X,* INFEASANLE TRUNK GEOMETRY *//) ISHAPE=0 RETUEN
C RZS C TEST 102 C OTER 111 5011 C TRUN 50	PHI2=AQS(A)S(AMAXI(-1, 0, AMINI(1, 0, ((R2-NY)/R2)))) SINPN2=SIY(PMI2) UTE CUTER RADIUS OF CUPVATURE Ri=((A-R2*51yPM2)**2+(A+NY)**2)/(2,*(B+MY)) PHI1=AQS(A)OS(AMAXI(-1, 0, AMINI(1, 0, ((R1-NY-8)/R1)))) X\$=A-R2*SIYPM2 IF (X\$.L\$.J\$.0) PHI1=6.2831952-PHI1 LZ=L=PMI1**Q IS RESULTANT RADIUS FOR COMPUTED LZEIN ITERATION IF(AQS(PHI2), LT.1.05-2) PHI2=1,0E-2 PZS=LZ/PHIZ IF 10L\$RANCE .GT. ERPOR IF(AYS(R2-R2S).LE.PIOL) GO TO \$0 RZ=(R2+R2S)*0.\$ CONTINUE ONLY ATED 50 II 125 WITHOUT SUCCESS, ERROR RETURN CONTINUE ONLY ATED 50 II 125 WITHOUT SUCCESS, ERROR RETURN CONTINUE ONLY ATED 50 II 125 WITHOUT SUCCESS, ERROR RETURN CONTINUE ONLY ATED 50 II 125 WITHOUT SUCCESS, ERROR RETURN CONTINUE ONLY ATED 50 II 125 WITHOUT SUCCESS, ERROR RETURN CONTINUE ONLY ATED 50 II 125 WITHOUT SUCCESS, ERROR RETURN CONTINUE ONLY ATED 50 II 125 WITHOUT SUCCESS, ERROR RETURN CONTINUE ONLY ATED 50 II 125 WITHOUT SUCCESS, ERROR RETURN CONTINUE ONLY ATED 50 II 125 WITHOUT SUCCESS, ERROR RETURN CONTINUE ONLY ATED 50 II 125 WITHOUT SUCCESS, ERROR RETURN CONTINUE ONLY ATED 50 II 125 WITHOUT SUCCESS, ERROR RETURN CONTINUE ONLY ATED 50 II 125 WITHOUT SUCCESS, ERROR RETURN CONTINUE ONLY ATED 50 II 125 WITHOUT SUCCESS, ERROR RETURN CONTINUE ONLY ATED 50 II 125 WITHOUT SUCCESS, ERROR RETURN CONTINUE ONLY ATED 50 II 125 WITHOUT SUCCESS ATED TO THE SUCESS ATED TO THE SUCCESS ATED TO THE SUCCESS ATED TO THE SUCCESS A

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C COMPUTE GEOMETRY TERMS	
SINPHZ=SIN(PHIZ)	· · · · · · · · · · · · · · · · · · ·
SINPHR=SINPHZ=RZ	•
DZ=D/Z.+SINPHR	·
1:02=0=1 X402	
BCDZ:BETA-JZ-02-0.5	
YH+E)/(CHONIS-A)+6=X	.013
C COMPUTE AREAS OF TRUNK SEC	
A1=PHI2/2.3*R2**2	
AZ= (92-HY)/2.0*SINPHR	
A3=PHI1/2.3*R1**2	
A4=X-9/2.0	
AS= (A-STHF4R-Y)/2.0 * (44-51
	12/2. 0)) **2*R2/(3.0*PH12)
X2=0.66567*SINPHR	74.47 33346343443 443 445444
	11/2.0))**2*?1/(3.0*PHI1)
X4=A-0.333333*X	·
X5=SIN=HR+0.333333*((-SINPHR+X)
S=2.0*L3+6.23313*02	
6A=A1+A3+A3-A2+44	
TX=E1+X1-B2+XZ+B3+X3-A	
IF(ICALL.GT.0) SO TO	
C SAVE TRUNK GEOTITRY TIRMS	FOR END TRUNK CALCULATIONS
R1I=R1	•
R2I=62	
. PHI1I=PHI1	
PHI21=PHI2	
L1I=L1	
rsI=rs	
A1I=A1	
A2I=A2	
SINPHSI=SIVPHS	
SINPHRI#SIYPHR	
X1I=X1	•
X21=X2	
A1M42 I = A1+42	
\$1=5	
85T4021+3ET4+02	
X12=(X1*A1-Y2*A2)/A1H/	21
DYAMA 31 + (D*0. 5 + K1 2) *A	
C202HRI=02*92*0.5*951	
0021=0ELX+32	
BD021=881A+02+02+0.5	
20 CONTINUE	•
C COMPUTE TRUNK SEGMENT ARE	L-VOLUME CUSHION AREA
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	AT# (R21-HYI*YGH(I)) *0.5*R2I*SINPH3
	46447+46+4*
	Apon11-211-2414-0.5
	49=(R11-HY10YGH(I))*0.5*R11*SINPH4
	• • • • • • • • • • • • • • • • • • •
	A10-49
	A11*A5
C COMP	UTE SICTOR CINTROIDS
• • • •	X6=SINPHR!-1.33333 (SIN(PHI3*0.5)**2)*921/PHI3
	x7.sinphqi-0.33333*P2:*Sinph3
	#8=\$[NPHR]+1.3333733*(SIN(PM]4*0.5)**2)*R1[/PH]4
• • • • • • • • • • • • • • • • • • • •	zg=SINPHRI+0.333333*R1I*SINPH4
	X10+X9
	X11+¥8
	PII2=PI*0.3
	1F(PH14.L1.P112) GO TO 50
	MIN GREATER THAY 90 DEGREES, SET TO 90 DEGREEN
W 47 P	
	PHI4+PII2
	SINPHESIN(PMIE)
	A10=(R1I-HYI+YGH(I))*R1I
	YAN-STADMOTAN. SORIT
•••	X10*SINPHRI*0.5*R1I
	Witch Haditania Att
	#1105TNPHR+1,33333E-15TH1FHT4-0-51-21-817/PHI4
50	CONTINUE
E COME	IUTE TRUNK AREA CHANGE
_R_WW.	A CHARLES A MARIA A A A A
	ATKR([]+A6447+A5-A9
	AT496(I)+6447+411-410
	XFR=(AE*1E-4**Y*+AB*Y+-A9*X3)/ATKR(I)
	XER9- (A6-X6-47-17-411-X11-A10-X10)/ATKRB(I)
*	UTE TRUNK VOLUME CHANGE
CCOMP	
	#1K#4{II}=B174*(Q*Q+S*YER)*AIK <u>R{I}</u>
	¥ 1KRE{I}=&1<48(I)+951&*(O+0.5+×6R#)
	VTKQ(I)=2, *VTKR1(I) =VTKR1(I)
•	XCP=(A6*X6-A7*X7)/A6MA7
	ACCOUNTS AND A TOTAL AND A TOT
CCON	UTE TRUNK EXIT AREAS
	ATKCHI(I) = FLOAT(IFIX((L2I-LX-R2I+PHI3)/SH+1.0)+NH)+ABUSI
	ATKATTITI - PLOATITETY (ILTI-L-L-LY-LOATINX-1) - SH-R1J-PHILI/SH-1.01-NH
	A A A A A A A
1) *A9081
	ATKCHR(I) =FLOAT(IFIY((LZI-LY)/SH+1.C) *NH) *AUDSI-ATKCHI(I)
	TERMONTA-(1) ITANTA-(1) INCHICLE-12CEA-PMF (1) PTANTA
	PERI(I) #9ETA* (ORSP+OZI+RIIFSINPHL)
A	UTE CONTACT PIGITER
U COM-	
-	ATKCHI(S) + 127A+1.4+ (02150-045+2)
C C041	UTE TRUNK CONTACT AREA .
	ATKCHR (11 = 31TA = 0.5 * 1 (02] = 811 * \$140H4) **2 - D215Q}
	ACHR(I) +AT (CNI(I)
	PRINTER THE TREE PRINTER PRINTER
"0.CO41	UTE CUSHION VOLUME CHANGE
	VCHR(I) == 0:TA = A 5 MA 7 * (0 * 0.5 + VCR)
C CON	PUTE GAP APIA CHRUGE
	AGAPR(1) = A 7 A P T (1)
	ANCE OF SEIMENT PRESSURE CONTERS FROM CUSHION CENTER
29	KR-021-R11784MH4
	AF1=C?I-92IPSINPH?
· · · · · · · · · · · · · · · · · · ·	##2+1.33355+514(0ETA+0.5)/3ETA+(RR++3-RR1++3)/(RR+RR-RR1+RR1)
	KGO-1886(1)
	GO TO (61,23,23.66,63.23,23.66).KGD
61	XCH(I) =-RLSH-7EDRCS
	\$GH(1)=95039N
	# TK () +- RL H- x x 2 * CO \$ OEL
	ATMITTED TO A RESULT OF THE PARTY OF THE PAR
	\$1Killexxs.2xnOff
	60 70 17
	XCH(I)=RLSH-7ED9SH
	ZCH(1)+0201C9
	** KIII + RL E-1+ K X Z * 9 I NOCL
	ZYK(11+xx2*0050\$L
	60 70 17
4.6	XCH(I) = RLSH+ DEDRCS
77	AURIST TREAT 175 VRU 3

			المهالين والمفقى المفاري والمالية المالية المالية والمالية والمالية والمالية والمالية والمالية والمالية والمال
		2CH(1)	-BEDRSN
		XTK(I)	STRANKS.COZDET
		ZTK(I)	-XY 1 SINCEL
		GO TG	,
4			RL3H-9E3P-HC1S
•			- 9E 29CS
	,	A15(1)	-RLS4-XX2*SINDEL
	4	SIKITI	- xx2°COSOFL
_	(GO TO	
	• • • • •	•••••	
C			
_C	TRUN	K GRCU	D CONTACT TOATHCO O
C	STRA	IGHT P.	RT OF TRUNK
1	23 (CONTIN	
C	COMP	UTE DE	DRMATION ANGLES
•		DHY - 11	2_ /HY_YGU / 1 \
		PMT TEA	OS (47471 (-1.0, AMIN1 (1.0, RHY)))
		Duv + 11	
	'	DMT :	10 (14 A X 1 (-1.) A M I M I (1. 0. A H Y)))
	00 7	D 4 M 5 C 2	ZENTALS JHLY OHCE
			SIN (PHI3)
			SIN(PHI4)
C			TIAL TERMS
			2-R?-SINPH3)
			(2k_1/2k
			COS (DELTA(I))
		SINDEL	SINCELEA(I))
	1	BEDRSN	SITIZEDRSPESINGEL
C	COHO	UTE RE	DVAL SECTORS
- ₹	• • •	46#R2+	2+ PH 13+ 0.5
			HY +YGH(I) 1+0.5+RZ+SINPH3
		46MA7 #	
		4.6-214	1+P414+0.5
	• • • • •	40-13+	HY +YGH(I))*0.5*R1*SINPH4
		A10=43	
	'	A11 = A8	
_	COMO	116 64	TOP CENTROIDS
	CORP	U 12 22	HR-1.333733* (SIN(PHI3*0.5)**2)*RZ/PHI3
	}	X7=51N	4R-).333333*RZ*SINPH3
		X6=21N	HP+1.3333339 (SIN(P414*0.5)**2)*R1/PH14
			IR+0,333333991 <u>*SINPH4</u>
		X10 = X9	
_		X11 = X8	
		PIIZED	
_		IF(PH]	LT.P112) GO TO TO GREATER THAN 90 DEGREES, SET TO 90 DEGREES
C	IF PI	HI4 IS	GREATER THAN 90 DEGREES. SET TO 90 DEGREES
		PHI 6=P	
		SINPHA	SIN(PHI4)
		410=(9	-HY+YGH(I)) •R1
			PH + + 0 . 5 + 41
		411=91	91+0HTL+0, \$
•		X11451	PHP+1.3333 433 4574 (STN (PHI4+0.5) ++2) +R1/PHI4
1	70	CONTIN	
<u>'</u> نے''	COMP		NK AREA CHANGE
·			•AF 447 + A 3 - A 9
			*A54A7+A11-A10
			,-a, ,a, ,-a, ,-a, 0
C			NK VOLUME CHANGE
			14#1/4/11/40661
			PATERNIES TO THE TANK
_			· 7. •VTKR4([]-VTKR3([)
C			4101 VOLUME CHANGE
			•-D:LX*45MA7
C	COHP	UTE TR	NK ETTT AREAS
	1	ATKATI	I) #FLOAT (IF IX ((L1 - L+LX+FLOAT (NX-1) *SH-R1*PHI4)/SH+1. 0) *NH)

		ATKCHI(1) = FLOAT(IFIY((L2-Lx-R2+2HI3)/SH+1.)+NH)+ADS
		ATKCHR(I)=FLOAT(IFIY((LZ-LX)/SH+1.0)*NH)*ADS-ATKCHI(I)
-		ATKATR(I) = RUN+ADS-ATKCHI(I)-ATKATI(I)-ATKCHR(I)
		PERI(I)a2. *DELX
C	COM	PUTE TRUNK CONTACT PERIMETER
		PUTE TRUNK CONTACT APEA
•	COM	ATKCN1(1)= 22*S14043*CELX
_		ATKCHOII)=R1-SINPH4-CELX
Ç	COM	PUTE GAP ARIA CHANGS
		ACHR(I)=AT(CNI(I)
•		AGAPR(II=ASAPI(I)
		KGO=ISEG(I)
C	COM	PUTE SIGNENT CONTACT CENTER OF PRESSURE FOR CUSHION AND TRUNK
		GO TO (17, 12,62,17,17,66,66,17),KGO
. 6	2	XCH(I)*XCX(I)
-	_	ZCH(I)=0.5*()2-92*SINPH3)
-	-	XTK(I)=XCX(I)
		2TK(1)=02+).5*(R1*SINPY4-92*SINPH3)
		GO TO 17
. 6	•	xCH(1) * XGX(1)
		ZCH(1)=-0.3*(02: R2*SINPH3)
_		XTK(I)=XGX(I)
		ZTK(1)=-(02+0.5*(R1*SINPH4-R2*SINPH3))
_ 1	7	CONTINUE
C.		
C	PART	T 3 SUMMATION OF SEGMENA AREAS VOLUMES
Ċ		
Ċ		•
ċ	SET	TOTAL AREA AND VOLUMES TO ZERO
•		ATKCH=0.0
		Y*K*0.0
		• • • • •
		ACH=0.0
		ATKCH=0.0
		ATKAT = 0.9
		VCH=0.0
		AGAP=C.0
		ATKATC=0.
	_	ATKC+C+0.
C	LOOP	P CN SEGMENTS TO FIND TOTALS OF AREAS AND VOLUMES.
		00 30 I=1.NSTOP
		VTK=VTK+ (YTKI(I)-VTKP(I))
		ACH=ACH+ (ACHI(I)-ACHR(I))
	 -	ATKCH#ATKCH+ATKCH1(1)
		ATKAT#ATKAT+ATKATI(I)
		VCM=VCH+ (VCMI(I)-VCHP(I))
		ATKCh=ATKCH+ATKCHI(I)+ATKCHR(I)
		AGAP=AGAP+ (AGAPI(I)-AGAPR(I))
		ATKATG=ATKATC+ATKATR(2)
		ATKCHC+ATKCHC+ATKCHR(I)
3	0	CONTINUE
		AGAP=AMAK1(AGAP,).0)
		VTK=&P&Y1 (). 0. VT<)
		VCH=AMAX1 (3.0, (VCH+VCH9))
		VCH= AMAY1 (), 0, VCH?
		ATKCH=AHAX1(0,000,ATKCH)
		ATMAT = AMATIA OO ATMATI
	-	ATKAT=AMAX1(0.00J.ATKAT)
		ACH-AMAX1(),0,ACH)
- .		ATKATC = AMAK1 (0.0 , ATKATC)
_	_	ATKCHC=AMAX1(6,3,ATKCHS)
.Ç_	F0	DAGE SUM OF NOTZLE AREAS TO BE EQUAL TO TOTAL NOZZLE AREA
		SUM=ATKAT+1FKCH+AFKATC+ATKCHC
		ATKCH=ATKCH/SUH+ATOTAL SATKAT#ATKAT/SUM+ATOTAL
- •		ATKCHC-ATKCHC/SUM-ATOTAL SATKATC-ATKATC/SUM-ATCTAL
		RETURN
-		END
		SUDRCUTINE STIFF. TZ. TX. DERY, IPP, PPLM. YPLM. VTK. DFANX. DV FK. PTK. DVCH.

<pre>#YCG.CVCMP.9CM.VCM.SINKPT.PHIE.DPHI .THETAE.DTMETA.CKK.PAT.GG.MY1.G</pre>
YEC, HASS, RPH, VELY, SIE, RHO, AGAP, ACH, AYK
XAT.ATKCH.ATKCN.ATKATC.ATKCHC.CAF.CEHFX.CGAP. ACHR.ATKCHI.ATKCH
CR.PERI.XCH.7CH.XTK.ZTK.4CHI.YGH.CPLTK.QTKCH.QTKAT.QCHAT)
C DYNAMIC FAR VERSION FOR FMA.
C STATE EQUATIONS FOR THE DYNAMIC SYSTEM
REAL MASS
C FOLLOWING SUBROUTINIS ARE CALLED TO UPDATE VALUES OF
C FORCES, TORGUES AND FLOWS. GIVEN THE NEW VALUES OF THE
C STATE VARIABLES
DIMENSION DERY (13) + ACHI (32) + ACHI (32) + ATKCNI (32) + ATKCNI (32) + PERI (32
X3.XCH(32), 23H(32).XTK(32), 2TK(32), YGH(32)
CC=+1-175AATFN=-796 SCPT=-6 SCTAR-4 SOVENTED-
CTC=,4 3FF=0. HDC=1. 3PHA=155. \$U=0.03 APITY=,69A SDAMPC=1.2 \$ATFAM=,072
MOCE1. 3PHA=155. SUEG.03
APLTK=.698 SDAHPC=3.2 SAIFAN=.072
CENFZ=0. ENSTOP=32
C SUBROUTING TO FIND FLOW AND PRESSURE VALUES DURING DYNAMIC SIMULATION
11RH0*2,0/3H0
C PLEMUN TO TRUNK FLOW
SYGN=1.0
1F((PPLM-PTK).LT.0.0) SIGN=-1.0
OPLTK*SIGN*CPT*40LTK*SORT(ABS(TIFHO*(PPLH-PTK)))
C TRUNK TO CUSHION FLOW
SIGN=1.
IF((PTK-PC4).LT.0.) SIGN=-1.
OTKCH+SIGN*CTC+SORT (A9S (TIRHO*(PTK-PCH)))*(ATKCH+0.66667*ATKCHC)
C TRUNK TO ATHOSPHERE FLOW
SIGN#1.0
IF(PTK,LT,0.0)SIGN=-1.
OTKAT=SIGN*CTA*SORT (TIRHO*A)S(PTK))* (ATKAT+0.66667*ATKATC)
C CUSMION TO ATMOSPHERE FLOW
SIGN=1.0
IF(PCH.LT.).01 SIGN=-1.0
QCHAT=AGAP *CGAP * SORT (TIPHO + ARS (PCH)) *SIGN
C FORCES AND TOPOUSS ASSOCIATED WITH A PARTICULAR ACLS ORIENTATION
C ARE CALCULATED
C CALCULATE TRANSCRUTHLS ONLY ONCE
CSSCS=COS (PHIE) *SIN (THETAE) *SIN(SIE) -COS (SIE) *SIN (PHIE)
GPCT=COS(FHIE) *COS(THETAE)
C CLEAR TOTAL FORCES AND TORQUES TO ZERO
FORCT=0.D
)TPX=0.0
TTPZ=0,0
1CPX=0.0
1CP2*0.0
TORF7=0.0
TOROTX=0.0 TOROT7=0.0 SFORGEY=0. STOP JUEX=0. STCRCUEZ=0.
TORULTAGE STORES SION SURANDE STORESTE INDUCTAGE
C FORCES AND TORDUES INDEPENDENT OF SEGMENTS INDIVIDUALLY
G HEAVE FORCES CUSHION AND TRUNK
FCP=PCH®ACH
FTP=PTK*ATKCN
C COMPUTE VELOCITY FOR DRAG FORCE
V=VELX*CSSJS+SIHKRT*CPCT
SIGN=1.
18 (V.GT.O.3) SIGN=-1.
C MEAVE DRAG FORCE
FDF=0,5*HD?*PH4*RHO*V*V*SIGN
C DRAG TOPOUE
10F7=FCF+C TYFX
TOFX==FDF * 2FNFZ
G PORCES AND TORIUES REPENDENT ON SEGMENTS INDIVIDUALLY
C FORCES AND TORDUES DEPENDENT ON SEGMENTS INDIVIDUALLY C SUM INDIVIDIOUAL SEGMENTS TO FIND TOTALS
C SUM INDIVICIONAL SIGHENTS TO FIND TOTALS 00 101 1-1-NSTO

TCP7=TCPZ+(XCH(1)-CC)+PCH+(ACHI(I)-ACHR(I))	
TCPX=TCPX-(ZSH(I)-FF)*PCH*(ACHI(I)-ACHR(I))	
T1PZ+T10Z+(XTK(11-CC)+(PTK+(ATKC).I(1)+ATKC)R(1)))	
TTPx=TTPx-{7T<{I1-FF}*(PTK*{ATKCH:I{I}+ATKCNR{I}})}	
IF ((ATKONICI).GT.O.).OR. (ATKONECI).ST.O.)) SO TO 111	
GO TO 101	
111 VELTE STRUCT COCTODAL (XTK(1)-CC) OTHETA (ZTK(1)-	FFI
FCPC=-VELT*DAMPC*PERI(I)	
FORCT=FORCT+FORO	
109012-109312-(x1K(1)-CC)-FORD	
TOROTX=TOROTX-(2TK(I)-FF) *FORO	-
1F(VELX.EO.0.0) GO TO 101	
TORFZ=TORFZ-(YCG-CPCT- PTK-(ATKCNI(1)+ATKCNR(1))*U	
101 CONTINUE	
C CUMMATION OF FREE AND TORQUE COMPONENTS	
C TOTAL HEAVE FORCE	
FORCEY# (FC>+FTP+FORCT+FDF)*GPCT	
FY+AHAX1 (F79CEY, 0.)	
C TOTAL TOPQUE X AXIS	
TORQUEX#TCPX+TTPX+TOROTX+TOFX	
TX=TOROUEX	
C JOTAL TORQUE Z AXIS	
TORQUEZ=TC=Z+TTPZ+TORQTZ+TOFZ+TORFZ	
TZ=TORGUEZ	
C STATE EQUATIONS	•
COOTHE STATE VARIABLES	
C 1)PFLPFLEMUN PRESSUPE (GAGE)	
C 2) PCM CUSHION PRESSURE (GAGE)	
C 3)PTKTRUNK PRESSURE (GAGE)	•
C 4) SINKRT VERTICAL SINK RATE, POSITIVE UPHARDS	·
C SIVCGCG ELEVATION	
C STOPHIPITCH RATE.VEHICLE FRAME	
C 7) DTHETA ROLL RATE. VEHICLE FRAME	
C BITHETAEEULFRIAN ROLL ANGLE	
C 9) PPIS EULERIAN PITCH ANGLE	
C_1015IEEULERIAN YAN ANGLE (APPROX. ZERO)	
G 111XV. DISPLN OF PRESSUPE RELIEF VALVE	į.
G 121 VV. VELCOITY OF PRESSURE RELIEF VALVE	
C 1312 FANX. FAN AIR INSERTANCE FLOW	
DERY(1) = (CKK+(P3L4+2A7)/VPL4)+(DFANX+QPLTK)	
JERY (3) * (CKK* (PIK +PAT)/VTK) * (UPLIK-OTKCH-OTKAT-OVTK)	•
G COSMION FLOW WHOME GEODING SERECT TRANSITION SOME	
QCHFT=QPLC++QTKCH-DVCH	
C. CALGULATE GROUND SPEECT TPANSIFION ZONE	
190UND=GG+HYI*(1.+GCC)	
BBOUND+GG+HYI	
C DETERMINE IF ACLS IN TRANSITION ZONE	
SFEYCO.GT. THOUNDI GO TO 13	
. IF (YCG.GT.BROUND) GO TO 14	
GO TO_16	
C ABOVE TRANSITION ZOVE	
13 QCMAT=QCHFT	
IFLAG#6	
10=0	
NO=0	
GO TO 15	
6	
C IN TRANSITION PONE	
_14 IfLAG*1	
NO.100	
10=1FIX(AD3((f9)UN)-YCG)/(f0UND-R9UUND)*FLOAT(NO)))	
IF(10.67.N2)10*N2	
60 TO 17	
e and the second	

16 NOW1 10=1 10=1 1FLAG=2 G COMPUTE CUSHION TO ATMOSPHERE FLOW 17 GCHAT**FLOAT(NO1**GCHAT**FLOAT(TO1/FLOAT(NO1**GCHAT** C CUSHION PRESSURE DERIVATIVE 25 DERY(2)**IO**LCH***OTKCH**-CCHAT**-DVGH**FVCH**FPCH**DERY(3)/(PTK**PTK))/ 1(VCH**/C(KK**(PCH**PAT1)**PDV2HP/PTK) C CUSHICN PRESSURE IS ZERO ARROYE TRANSITION ZONE 1F(IFLAG.E7.0.0) PCH=0.0 66 RETURN END PARAHETER VALUES**TD1AV=0 UMAX=20. MSS=77.5 GG= 1.5
TFLAGe COMPUTE CUSHION TO ATMOSPHERE FLOW TO QCHAT FLOATING) **OCHT** FLOATING) **QCHAT FLOATING) **QCHAT FLOATING) **QCHAT FLOATING) **QCHAT FLOATING) **QCHAT FLOATING) **QCHAT FLOATING FROM FRESURE DERIVATIVE SOERY (2) = (0)
TFLAGE C COMPUTE CUSHION TO ATMOSPHERE FLOW T
G COMPUTE CUSHION TO ATMOSPHERE FLOW 17
17
C CUSMION PRESSURE DERIVATIVE 15
DERY(2)=10-LCM+CTKCM-CC-43T-JVCM+CVCMF*PCH*DERY(3)/(PTK*PTK))/ 1(VCM/CCKC*(PCM+PAT1)+OVCMP/PTK) C CUSMICN PARSSURE IS ZERO A93VE TRANSITION ZONE 1F(IFLAG.E7.0.0) PCM=0.0 66 RETURN END PARAMETER VALUES=ID1AV=0
DERY(2)=10-LCM+CTKCM-CC-43T-JVCM+CVCMF*PCH*DERY(3)/(PTK*PTK))/ 1(VCM/CCKC*(PCM+PAT1)+OVCMP/PTK) C CUSMICN PARSSURE IS ZERO A93VE TRANSITION ZONE 1F(IFLAG.E7.0.0) PCM=0.0 66 RETURN END PARAMETER VALUES=ID1AV=0
1 (VCH/(CKK*(PCH+PAT1)+OVCHP/PTK) C CUSHICN PRESSUR: IS ZERO ABOVE TRANSITION ZONE 1 (IFLAG.E2.0.0.0) PCH=0.0 66 RETURN END PARAMETER VALUES*ID1AV=0 UHAX*200. MSS*77.5 GG= 1.5 ,FF=0. ,PMA=155. ,HOC=1. ,LS=6.125 ,D=617 -A=.695 E=.524.,L=5.17 ,HYI=1.00 , AH=3.66-6 ,SH=.0833 ,LX=0.80 AIF=.072 APC=0. ,APT=.698 ,APA=0. ,AAT=.796 ,VCD=0. DPV=8, FAT=2115.8 ,TEM=70. CCK#1.4 ,CPA=0. ,CAF=.5 ,CPC=0. ,CPT=.5 ,CTC=6 CTA=.6 ,CGP=.5 ,GEC=.1 . CFX= 1.17 ,CFZ=0. ,OPC=3.2 XA (C=0. ,XU (O=0. ,ZA (C=0. ,MAL(O=0. ,WA (C=0. ,XP1(O=2)))
C CUSHICN PRESSURE IS ZERO A93VE TRANSITION ZONE 1
IF(IFLAG.E7.0.0) PCH=0.0
66 RETURN END PARAMETER VALUES=TD1AV=0 UMAX=20. MSS=77.5 GG= 1.5 ,FF=0. ,PMA=155. ,MOC=1. ,LS=4.125 ,D=.417 .A=.695 E=.524.L=5.17 ,MYI=1.00 , AH=3.4E=4 ,SM=.0833 ,LX=0.80 AIF=.972 APC=0. ,APT=.698 ,APA=0. ,AAT=.796 ,VCD=0. DPV=8,
66 RETURN END PARAMETER VALUES=TD1AV=0 UMAX=20. MSS=77.5 GG= 1.5 ,FF=0. ,PMA=155. ,MOC=1. ,LS=4.125 ,D=.417 .A=.695 E=.524.L=5.17 ,MYI=1.00 , AH=3.4E=4 ,SM=.0833 ,LX=0.80 AIF=.972 APC=0. ,APT=.698 ,APA=0. ,AAT=.796 ,VCD=0. DPV=8,
END PARAMETER VALUES=ID1AV=0 UMAX=20. MSS=77.5 GG= 1.5 ,FF=0. ,PMA=155. ,MOC=1. ,LS=6,125 ,D=617 -A=.695 E=.524.,L=5.17 .HYI=1.00 , AH=3.66-6 ,SH=.0833 ,LX=0.80 AIF=.072 APC=0. ,APT=.698 ,APA=0. ,AAT=.796 ,VCD=0. DPV=8, FAT=2115.8 .TEM=70. CCK#1.4 .CPA=0. ,CAF=.5 .CPC=0. ,CPT=.5 .CTC=64 CTA=.6 ,CGP=.5 ,GSC=.1 . CFX= 1.17 ,CFZ=0OPC=3.2 XA LC=0. ,XU LO=0. ,ZA LC=0. ,MALC=0. ,HU LO=0. ,XP1LO=2
PARAMETER VALUES=ID1AV=0 UMAx=20. MSS=77.5 GG= 1.5 ,FF=0. ,PMA=155. ,MOC=1. ,LS=4.125 ,D=.417 -A=.695 E=.524.,L=5.17 .MYI=1.00 , AH=3.46=4 .SM=.0833 ,LX=0.80 AIF=.072 APC=0. ,APT=.698 ,APA=0. ,AAT=.796 ,VCD=0. DPV=8, FAT=2115.8 .TEM=70. CCK#1.4 .CPA=0. ,CAF=.5 .CPC=0. ,CPT=.5 .CTC=.4 CTA=.4 .CGP=.5 .GSC=.1 . CFX= 1.17 ,CFZ=0OPC=3.2 XA LO=0. ,XU LO=0. ,ZA LO=0. ,MALO=0. ,XP LO=0. ,XP LO=2
UMAX=20. MSS=77.5 GG=1.5 ,FF=0. ,PMA=155. ,MOC=1. ,LS=4.125 ,D=.417 .A=.695 E=.524.L=5.17 ,MYI=1.00 , AH=3.4£-4 ,SM=.0833 ,LX=0.80 AIF=.972 APC=0. ,APT=.698 ,APA=0. ,AAT=.796 ,VCD=0. DPV=8,
MSS=77.5 GG= 1.5 ,FF=0. ,PMA=155. ,MOC=1. ,LS=4.125 ,D=417 -A=.695 E=.524,L=5.17 ,HYI=1.00 , AH=3.4E=4 ,SM=.0833 ,LX=0.80 AIF=.972 APC=0. ,APT=.698 ,APA=0. ,AAT=.796 ,VCD=0. DPV=8, FAT=2115.8 ,TEM=70. ,CPC=0. ,CP7=.5 ,CTC=.4 CTA=.4 ,CG=.5 ,GEC=.1 . CFX= 1.17 ,CFZ=0. ,OPC=3.2 XA LC=0. ,XU LO=0. ,ZA LC=0. ,MALC=0. ,MU LO=0. ,XP1LO=2
MSS=77.5 GG= 1.5 ,FF=0. ,PMA=155. ,MOC=1. ,LS=4.125 ,D=417 -A=.695 E=.524,L=5.17 ,HYI=1.00 , AH=3.4E=4 ,SM=.0833 ,LX=0.80 AIF=.972 APC=0. ,APT=.698 ,APA=0. ,AAT=.796 ,VCD=0. DPV=8, FAT=2115.8 ,TEM=70. CTA=.4 ,CGP=.5 ,GEC=.1 . CFX= 1.17 ,CFZ=0. ,OPC=3.2 XA LC=0. ,XU LO=0. ,ZA LC=0. ,MALC=0. ,HU LO=0. ,XP1LO=2
E=.524,L=5.17 ,HYI=1.00 , AH=3.4E=4 ,SH=.0833 ,LX=0.80 AIF=.072 APC=0 ,APT=.698 ,APA=0 ,AAT=.796 ,VCD=0 , PAT=2115.8 ,TEM=70 , CKK=1.4 ,CPA=0 ,CAF=.5 ,CPC=0 ,CPT=.5 ,CTC=.4 ,CPA=.4 ,CGP=.5 ,GEC=.1 , CFX=1.17 ,CFZ=0 ,OPC=3.2 ,XA
E=.524,L=5.17 ,HYI=1.00 , AH=3.4E=4 ,SH=.0833 ,LX=0.80 AIF=.072 APC=0 ,APT=.698 ,APA=0 ,AAT=.796 ,VCD=0 , PAT=2115.8 ,TEM=70 , CKK=1.4 ,CPA=0 ,CAF=.5 ,CPC=0 ,CPT=.5 ,CTC=.4 ,CPA=.4 ,CGP=.5 ,GEC=.1 , CFX=1.17 ,CFZ=0 ,OPC=3.2 ,XA
AFF=.072 APC=0, APT=.698 ,APA=0, ,AAT=.796 ,VCD=0, DPV=8, FAT=2115.8 ,TEM=70, CKK=1.4 ,CPA=0, ,CAF=.5 ,CPC=0, ,CPT=.5 ,CTC=.4 CTA=.4 ,CGP=.5 ,GEC=.1 , CFX= 1.17 ,CFZ=0, ,OPC=3.2 XA LC=0, ,XU LO=0, ,ZA LC=0, ,MALLC=0, ,MU LO=0, ,XP1LO=2
APC=0APT=.698 ,APA=0. ,AAT=.796 ,VCD=0. DPV=8,
DPV=8,
CTA=.4, CGP=.5, GEC=.1 . CFX= 1.17 ,CFZ=0. ,CPC=3.2 XA LC=0. ,XU LC=1. ,ZA LC=0. ,MALLC=0. ,MU LC=0. ,XP1LC=2
CTA=.4, CGP=.5, GEC=.1 . CFX= 1.17 ,CFZ=0. ,CPC=3.2 XA LC=0. ,XU LC=1. ,ZA LC=0. ,MALLC=0. ,MU LC=0. ,XP1LC=2
CTA=.4 .CGP=.5 .GEC=.1 .
XA LO=0XU LO=1ZA LO=0MALLO=0HU LO=0XP1LO=Z
₹9760#U₹4 60#9YDALD=063060#0.
LB LD=0N97LD=7N3 LC=0N0ALD=0RU0LD=1B LD=19.
TCOEN=8.4 THREN=2353 . YO FN=-6.1, GAYEN=1 GAZEN=0
P1 TF=17.46.70 TF=0Z1 TF=158.73
20 76 2454.73
71 TF 2*0.,P0 TF 2*153,73,P1 TF 2*17.46.
ZI TP ZEU.,PO TF Z*195./5,P1 TF Z*17.46.
GKIIT 3=1
C1 MC 1=1.2.C2 M2 1=3.75,C3 MC 1=2.5,C4 MC 1=0GKIIT 7=1GKLIT 7=1.
GKIIT 8=-1.,GKLIT 8=1.,C1 MC 2=1.54.C2 MC 2=5.75.C3 MC 2=2.5,C4 MC 2=0,,
GKIIT 5=1GKLIT 9=1GKIITID=-1GKLITID=1ALSAV=0S AV=76.
UM AV=0 VM AV=+0
MA1LO=77.5.C LC=45KLTT 1=15KLTT 1=1IXXSO=2414., IYYSO=1840
12750=+002IXZSD=-20J
FY153=0 "Y253=0. , T2253+0 FX253=0. , TX153+0 TZ153=0
fx353=0, ,fx353=0, ,F2353=0,
X0 L0=-39.692.740L0=12366.YP L0=335692.70 L0=-8.9257.
X0 L0=-39.692.740L0=12366.YP L0=335692.70 L0=-8.9257.
X0 L0=-99,692.74DL0=12366.YP L0=335692,20 L0=-8.8257, MADL0=75699,YR LD=.12081.L0 L0=-113.74.X02L0=865052.M0 L0=-175.86,
X0 L0=-39,692.74DL0=12366.YP L0=035692,20 L0=-0.0257, MADL0=75699,YR L0=.12081.L0 L0=-113.74.X02L0=065052.M0 L0=-175.86, YORLD=350.17.LR L0=-15.316.NP L0=-11.851.Z0 L0=-10.967.Z0EL0=-15.562,
X0 L0=-99.692.7ADL0=12366.YP L0=-,035692,20 L0=-8.0257, MADL0=-,75699.YR L0=.12081.L0 LD=-113.74.402L0=065072.M0 L0=-175.86, YORL0=350.17.LR L0=-12.316.NP LD=-11.851.20 L0==10.967.7CEL0=-15.562, LORLD=607.NR L0=100.33.M0 L0=13.725.M0EL0=-865.13,L0ALC=-3.6745.
X0 L0=-99.692.ZADL0=12366.YP L0=035692.Z0 L0=-8.0257. MADL0=75699.YR L0=12081.t0 L0=-113.74.X0;L0=065082.M0 L0=-175.86. YORL0=350.17.LR L0=-12.316.NP L0=-11.851.Z0 L0=-10.967.Z0EL0=-15.562. L0RL0=607NR L0=100.33.M0 L0=13.725.M0EL0=-865.13,L0AL0=-3.6745. NORL0=-119.
X0 L0=-99.692.7ADL0=12366.YP L0=035692.20 L0=-8.0257. MADL0=75699.YR L0=.12081.L0 LD=-113.74.402L0=065052.M0 L0=-175.86. YORL0=350.17.LR L0=-14.116.NP LD=-11.851.72 L0==-10.967.7CEL0=-15.562. L0RL0=607NR L0=100.33.M0 L0=13.725.M0EL0=-865.13,L0ALC=-3.6745. NDRL0=-119. THITIS CONTITIONS
X0 L0=-99.692.7ADL0=12366.YP L0=035692.20 L0=-8.0257. MADL0=75699.YR L0=12081.L0 L0=-113.74.402L0=065072.M0 L0=-175.86. YORL0=350.17.LR L0=-12.316.NP L0=-11.851.20 L0=-0.065072.CEL0=-15.562. LDRL0=607NR L0=100.93.M0 L0=13.725.402L0=-865.13,L0AL0=-3.6745. NORL0=-119. INITIAL COMDITIONS PPLEM=137.93.PTKFM=126.06.PC4FM=0. ,TH EN=1515.8.U SD=17.033.
X0 L0=-99,692.74DL0=12366.YP L0=035692.20 L0=-8.0257. MADL0=75699.YR L0=12081.t0 L0=-113.74.X0;L0=065052.M0 L0=-175.86. YORL0=350.17.LR L0=-12.316.ND L0=-11.851.Z0 L0=-065052.M0 L0=-15.562. L0RL0=607.NR L0=100.33.M0 L0=13.725.40;L0=-865.13,L0AL0=-3.6745. NORL0=-119. INITIAL COMDITIONS PPLFM=137.93.PTKFH=126.05.PCMFH=0. ,TM EN=1515.8.U SD=17.033. N SD=6.5236.H SD=0P SD=00 SD=0.0 R SD=0.
X0 L0=-99,692.74DL0=12366.YP L0=035692.20 L0=-8.0257. MADL0=75699.YR L0=12081.t0 L0=-113.74.X0;L0=065052.M0 L0=-175.86. YORL0=350.17.LR L0=-12.316.ND L0=-11.851.Z0 L0=-065052.M0 L0=-15.562. L0RL0=607.NR L0=100.33.M0 L0=13.725.40;L0=-865.13,L0AL0=-3.6745. NORL0=-119. INITIAL COMDITIONS PPLFM=137.93.PTKFH=126.05.PCMFH=0. ,TM EN=1515.8.U SD=17.033. N SD=6.5236.H SD=0P SD=00 SD=0.0 R SD=0.
X0 L0=-99,692.74DL0=12366.YP L0=035692.20 L0=-8.0257. MADL0=75699.YR L0=12081.t0 L0=-113.74.X0;L0=065052.M0 L0=-175.86. YORL0=350.17.LR L0=-12.316.ND L0=-11.851.Z0 L0=-065052.M0 L0=-15.562. L0RL0=607.NR L0=100.33.M0 L0=13.725.40;L0=-865.13,L0AL0=-3.6745. NORL0=-119. INITIAL COMDITIONS PPLFM=137.93.PTKFH=126.05.PCMFH=0. ,TM EN=1515.8.U SD=17.033. N SD=6.5236.H SD=0P SD=00 SD=0.0 R SD=0.
X0 L0=-99,692.74DL0=12366.YP L0=035692.20 L0=-8.0257. MADL0=75699.YR L0=12081.t0 L0=-113.74.X0;L0=065052.M0 L0=-175.86. YORL0=350.17.LR L0=-12.316.ND L0=-11.851.Z0 L0=-065052.M0 L0=-15.562. L0RL0=607.NR L0=100.33.M0 L0=13.725.40;L0=-865.13,L0AL0=-3.6745. NORL0=-119. INITIAL COMDITIONS PPLFM=137.93.PTKFH=126.05.PCMFH=0. ,TM EN=1515.8.U SD=17.033. N SD=6.5236.H SD=0P SD=00 SD=0.0 R SD=0.
X0 L0=-99.692.7ADL0=12366.YP L0=035692.20 L0=-8.0257. MADL0=75699.YR L0=.12081.L0 L0=-113.74.40cL0=065072.M0 L0=-175.86. YORL0=350.17.LR L0=-12.516.NP L0=-11.851.70 L0=-0.065072.MD L0=-175.86. LDRL0=607NR L0=-0.33.M0 L0=13.725.MC2L0=-865.13,L0ALC=-3.6745. NORL0=-119. INITIAL COMDITIONS= PPLFM=137.93.PTK f=125.06.PCMFM=0. ,TH EN=1515.8.U SD=17.033. V SD=6.5235.M SD=0. ,P SD=0. ,Q SD=0.0 R SD=0. ROLSD=0. ,PITSD==-1.0 .YAMSO=0. ,ALTSD=2.6 O.XI TF=0. X2 TF=0. ,X2 IT 7=0. ,X2 IT 5=0. ,X2 IT 3=0. X2 IT 1=0.XI TF 2=0X2 TF 2=0.,X2 IT 9=0.,X2 IT 1=0.
X0 L0=-99.692.7ADL0=12366.YP L0=035692.20 L0=-8.0257. MADL0=75699.YR L0=.12081.L0 L0=-113.74.40cL0=065072.M0 L0=-175.86. YORL0=350.17.LR L0=-12.516.NP L0=-11.851.70 L0=-0.065072.MD L0=-175.86. LDRL0=607NR L0=-0.33.M0 L0=13.725.MC2L0=-865.13,L0ALC=-3.6745. NORL0=-119. INITIAL COMDITIONS= PPLFM=137.93.PTK f=125.06.PCMFM=0. ,TH EN=1515.8.U SD=17.033. V SD=6.5235.M SD=0. ,P SD=0. ,Q SD=0.0 R SD=0. ROLSD=0. ,PITSD==-1.0 .YAMSO=0. ,ALTSD=2.6 O.XI TF=0. X2 TF=0. ,X2 IT 7=0. ,X2 IT 5=0. ,X2 IT 3=0. X2 IT 1=0.XI TF 2=0X2 TF 2=0.,X2 IT 9=0.,X2 IT 1=0.
X0 L0=-99,692.74DL0=12366.YP L0=035692.20 L0=-8.0257. MADL0=75699.YR L0=12081.t0 L0=-113.74.X0;L0=065052.M0 L0=-175.86. YORL0=350.17.LR L0=-12.316.ND L0=-11.851.Z0 L0=-065052.M0 L0=-15.562. L0RL0=607.NR L0=100.33.M0 L0=13.725.40;L0=-865.13,L0AL0=-3.6745. NORL0=-119. INITIAL COMDITIONS PPLFM=137.93.PTKFH=126.05.PCMFH=0. ,TM EN=1515.8.U SD=17.033. N SD=6.5236.H SD=0P SD=00 SD=0.0 R SD=0.
X0 L0=-99.692.7ADL0=12366.YP L0=035692.20 L0=-8.0257. MADL0=75699.YR L0=.12081.L0 L0=-113.74.40cL0=065072.M0 L0=-175.86. YORL0=350.17.LR L0=-12.516.NP L0=-11.851.70 L0=-0.065072.MD L0=-175.86. LDRL0=607NR L0=-0.33.M0 L0=13.725.MC2L0=-865.13,L0ALC=-3.6745. NORL0=-119. INITIAL COMDITIONS= PPLFM=137.93.PTK f=125.06.PCMFM=0. ,TH EN=1515.8.U SD=17.033. V SD=6.5235.M SD=0. ,P SD=0. ,Q SD=0.0 R SD=0. ROLSD=0. ,PITSD==-1.0 .YAMSO=0. ,ALTSD=2.6 O.XI TF=0. X2 TF=0. ,X2 IT 7=0. ,X2 IT 5=0. ,X2 IT 3=0. X2 IT 1=0.XI TF 2=0X2 TF 2=0.,X2 IT 9=0.,X2 IT 1=0.
X0 L0=-99.692.7ADL0=12366.YP L0=035692.20 L0=-8.0257. MADL0=75699.YR L0=.12081.L0 L0=-113.74.40cL0=065072.M0 L0=-175.86. YORL0=350.17.LR L0=-12.516.NP L0=-11.851.70 L0=-0.065072.MD L0=-175.86. LDRL0=607NR L0=-0.33.M0 L0=13.725.MC2L0=-865.13,L0ALC=-3.6745. NORL0=-119. INITIAL COMDITIONS= PPLFM=137.93.PTK f=125.06.PCMFM=0. ,TH EN=1515.8.U SD=17.033. V SD=6.5235.M SD=0. ,P SD=0. ,Q SD=0.0 R SD=0. ROLSD=0. ,PITSD==-1.0 .YAMSO=0. ,ALTSD=2.6 O.XI TF=0. X2 TF=0. ,X2 IT 7=0. ,X2 IT 5=0. ,X2 IT 3=0. X2 IT 1=0.XI TF 2=0X2 TF 2=0.,X2 IT 9=0.,X2 IT 1=0.
X0 L0=-99.692.7ADL0=12366.YP L0=035692.20 L0=-8.0257. MADL0=75699.YR L0=.12081.L0 L0=-113.74.40cL0=065072.M0 L0=-175.86. YORL0=350.17.LR L0=-12.516.NP L0=-11.851.70 L0=-0.065072.MD L0=-175.86. LDRL0=607NR L0=-0.33.M0 L0=13.725.MC2L0=-865.13,L0ALC=-3.6745. NORL0=-119. INITIAL COMDITIONS= PPLFM=137.93.PTK f=125.06.PCMFM=0. ,TH EN=1515.8.U SD=17.033. V SD=6.5235.M SD=0. ,P SD=0. ,Q SD=0.0 R SD=0. ROLSD=0. ,PITSD==-1.0 .YAMSO=0. ,ALTSD=2.6 O.XI TF=0. X2 TF=0. ,X2 IT 7=0. ,X2 IT 5=0. ,X2 IT 3=0. X2 IT 1=0.XI TF 2=0X2 TF 2=0.,X2 IT 9=0.,X2 IT 1=0.
X0 L0=-99.692.7ADL0=12366.YP L0=035692.20 L0=-8.0257. MADL0=75699.YR L0=.12081.L0 L0=-113.74.40cL0=065072.M0 L0=-175.86. YORL0=350.17.LR L0=-12.516.NP L0=-11.851.70 L0=-0.065072.MD L0=-175.86. LDRL0=607NR L0=-0.33.M0 L0=13.725.MC2L0=-865.13,L0ALC=-3.6745. NORL0=-119. INITIAL COMDITIONS= PPLFM=137.93.PTK f=125.06.PCMFM=0. ,TH EN=1515.8.U SD=17.033. V SD=6.5235.M SD=0. ,P SD=0. ,Q SD=0.0 R SD=0. ROLSD=0. ,PITSD==-1.0 .YAMSO=0. ,ALTSD=2.6 O.XI TF=0. X2 TF=0. ,X2 IT 7=0. ,X2 IT 5=0. ,X2 IT 3=0. X2 IT 1=0.XI TF 2=0X2 TF 2=0.,X2 IT 9=0.,X2 IT 1=0.
X0 L0=-99.692.7ADL0=12366.YP L0=035692.20 L0=-8.0257. MADL0=75699.YR L0=.12081.L0 L0=-113.74.40cL0=065072.M0 L0=-175.86. YORL0=350.17.LR L0=-12.516.NP L0=-11.851.70 L0=-0.065072.MD L0=-175.86. LDRL0=607NR L0=-0.33.M0 L0=13.725.MC2L0=-865.13,L0ALC=-3.6745. NORL0=-119. INITIAL COMDITIONS= PPLFM=137.93.PTK f=125.06.PCMFM=0. ,TH EN=1515.8.U SD=17.033. V SD=6.5235.M SD=0. ,P SD=0. ,Q SD=0.0 R SD=0. ROLSD=0. ,PITSD==-1.0 .YAMSO=0. ,ALTSD=2.6 O.XI TF=0. X2 TF=0. ,X2 IT 7=0. ,X2 IT 5=0. ,X2 IT 3=0. X2 IT 1=0.XI TF 2=0X2 TF 2=0.,X2 IT 9=0.,X2 IT 1=0.
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<u>Vita</u>

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As well, the thrusters would be set forward of the aircraft center of gravity and could be activated in tandum to aid in pitch control.

The Jindivik Remotely Piloted Vehicle, an Australian target drone, was fitted with an ACLS and taxi tests showed the instability and need for a stabilization system. Subsequent use of Jindivik wind tunnel and taxi test data served as the basis for the development of the roll/pitch control system presented in this paper. Due to computational problems with the air cushion model of the computer program, the controller designs could not be completely verified; but expected trends in pitch, roll, and yaw control were shown.